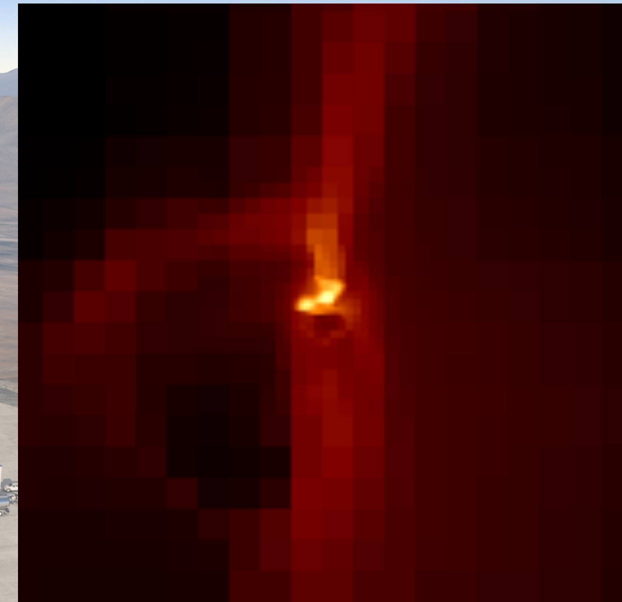
Detecting Pop. III Stars with HARMONI on the ELT



Kearn Grisdale

Collaborators:
Niranjan Thatte
Julien Devriendt
Miguel Pereira-Santaella

ESO
Instituto de Astrofisica de Canarias IAC
Durham University
University of Oxford
CSIC
RAL Space
ONERA THE FRENCH AEROSPACE LAB
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CRAL CENTRE DE RECHERCHE ASTROPHYSIQUE DE LYON
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Population III Stars

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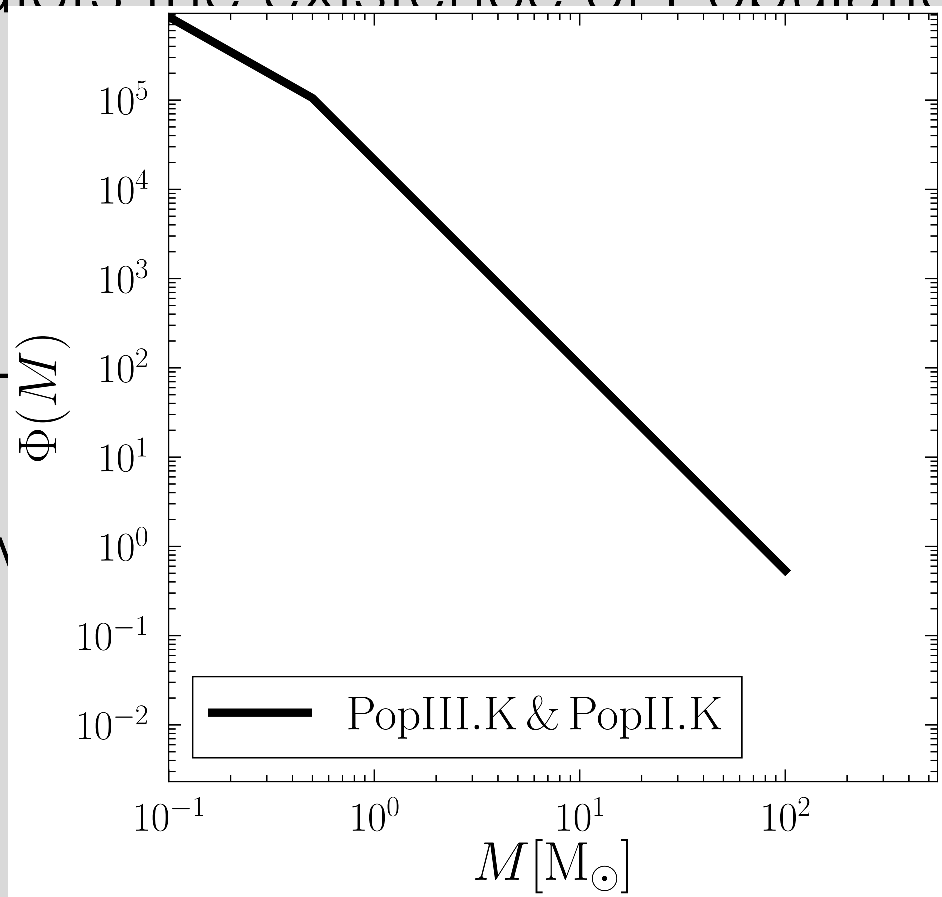

★First stars

★Primordial … H, He and traces of L…

★Presumed … $100\,\mathrm{M}_\odot)$

★Different I…

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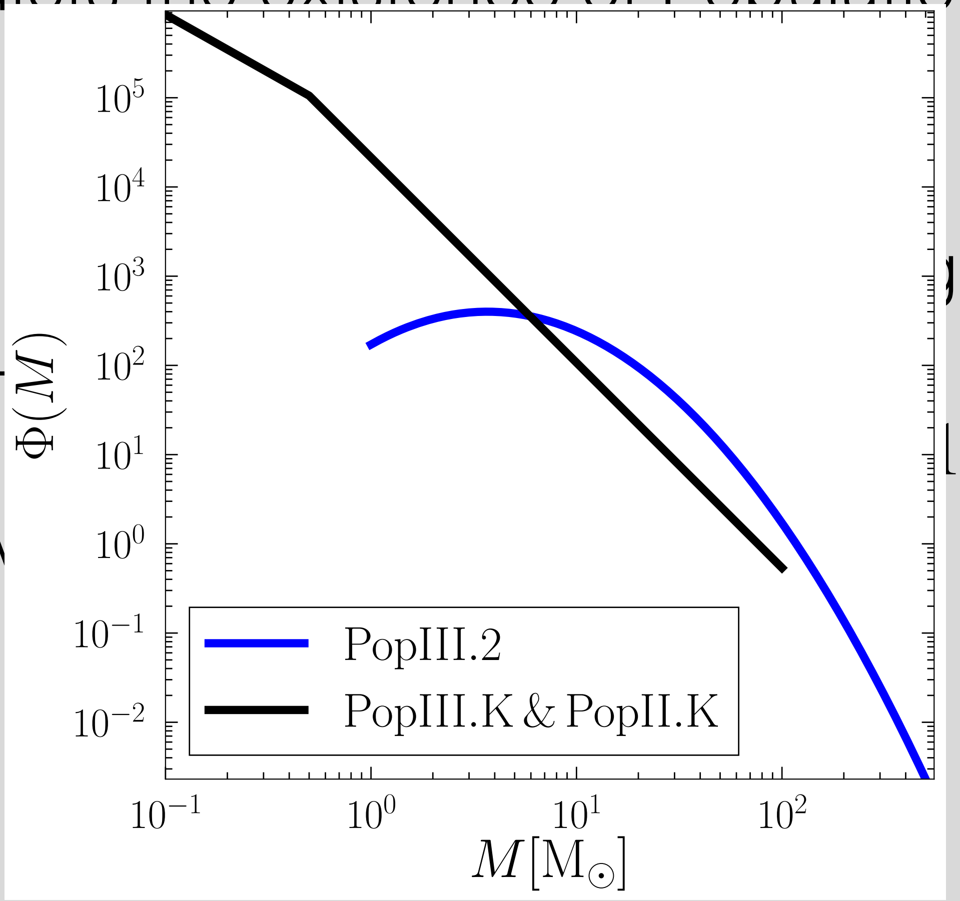

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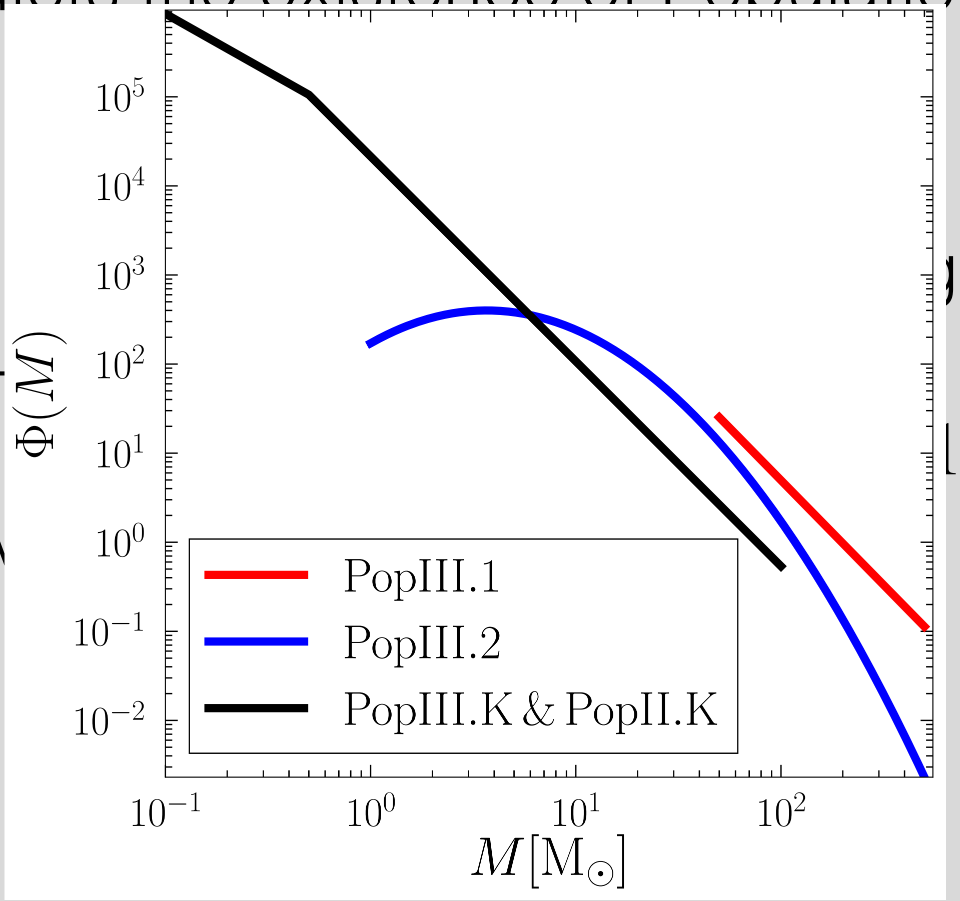

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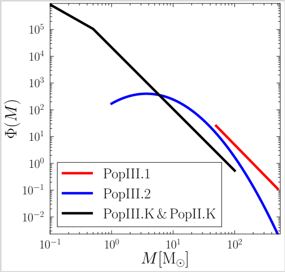

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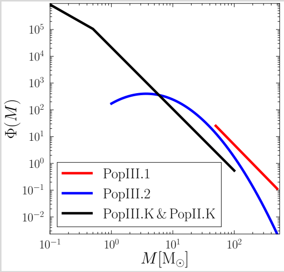

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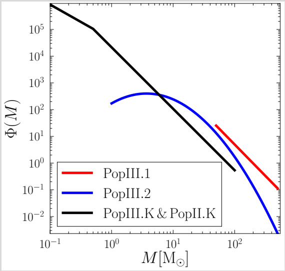
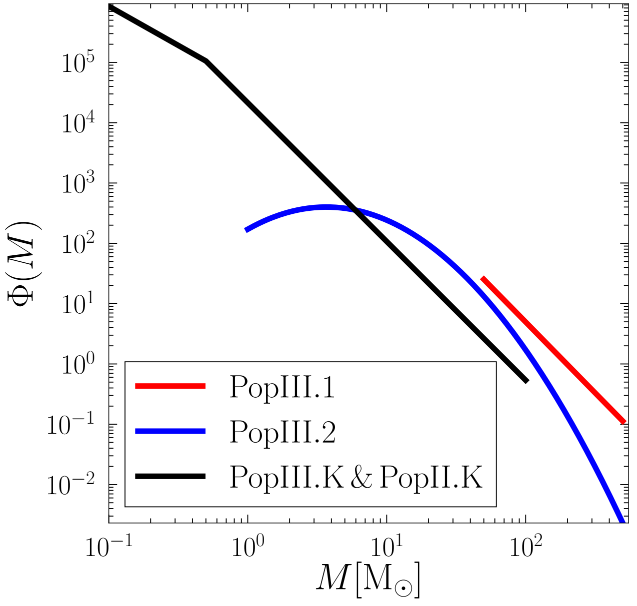
- ★ Needed for galaxy evolution (i.e. to produce metals for future star formation) theories



Signature of Pop. III Stars: HeIIλ1640

- ★ Due to large mass, Pop. III stars have the potential to completely ionise He.



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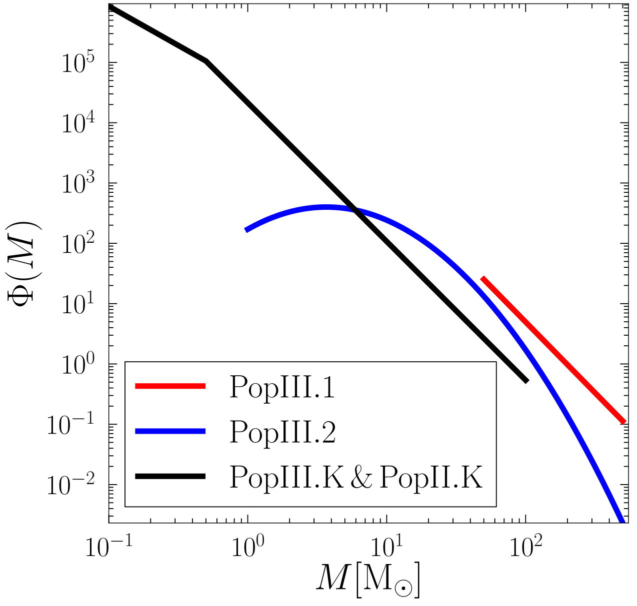

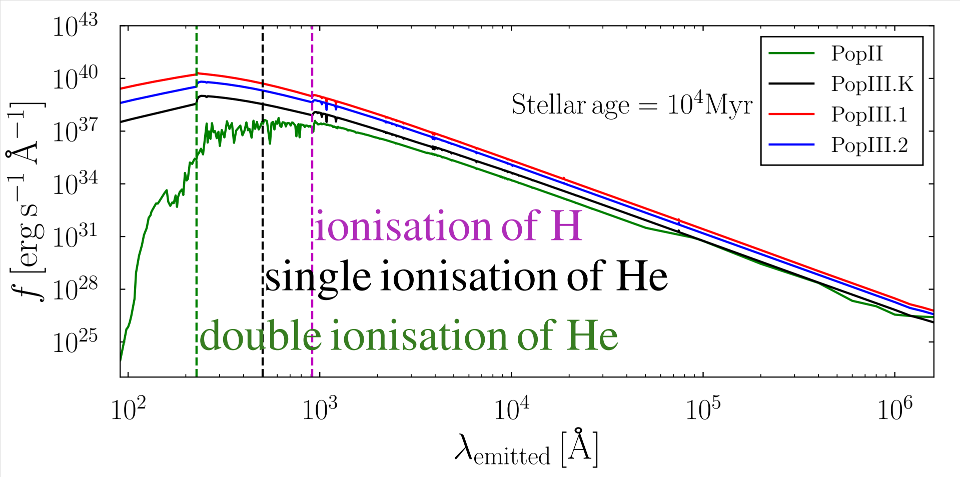

SEDs from Zackrisson et al., 2016

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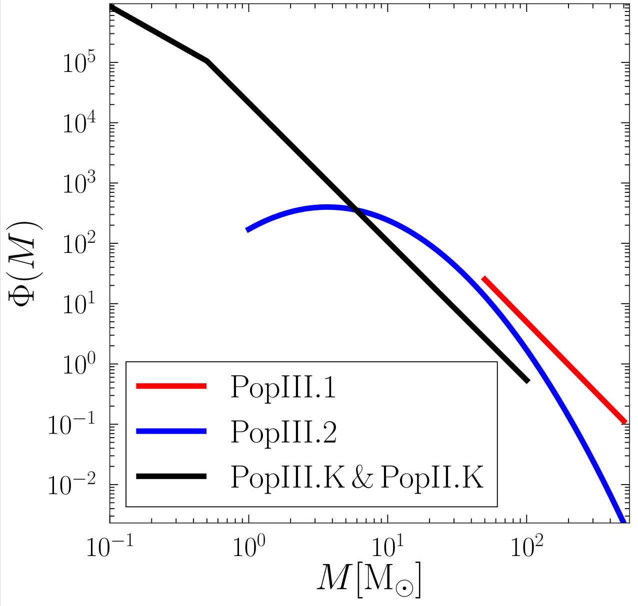

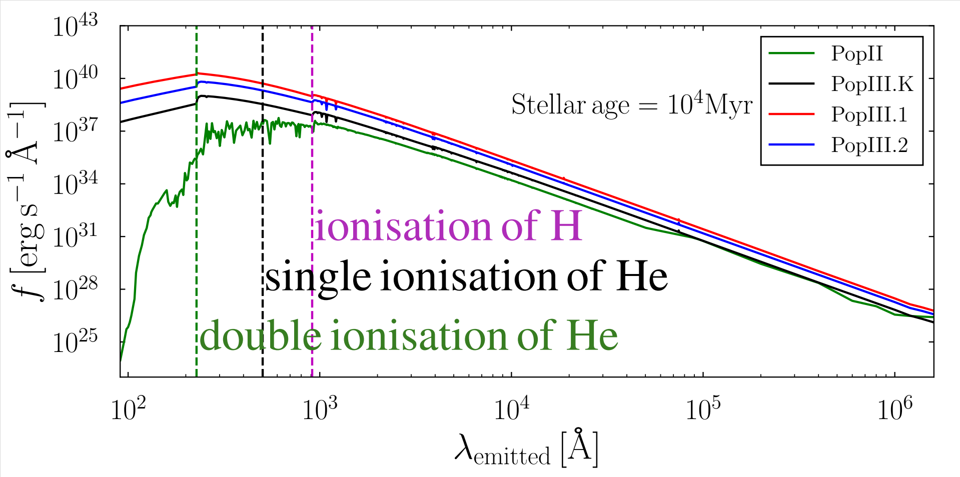

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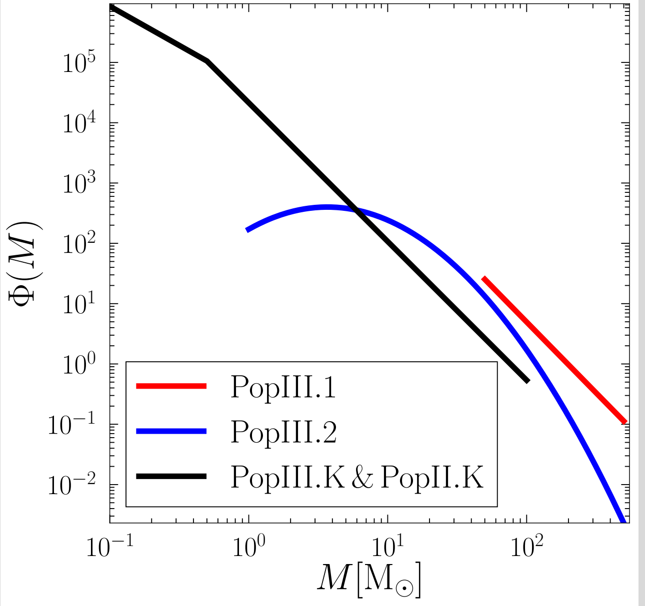

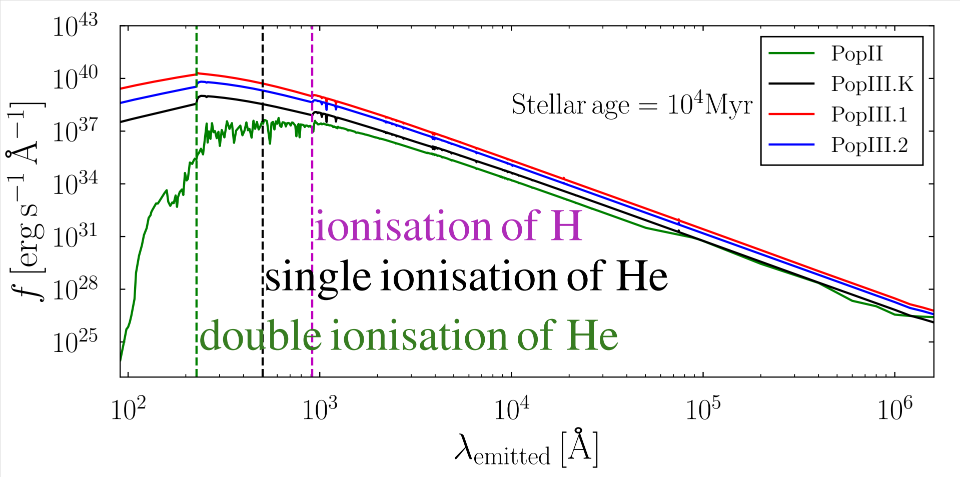

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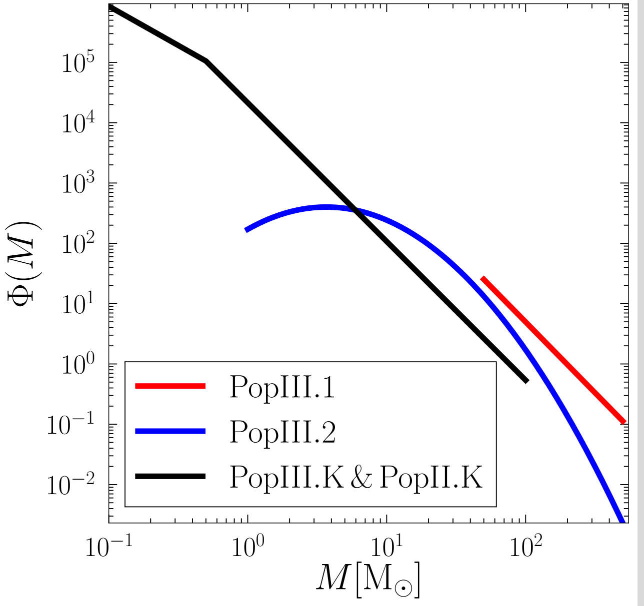

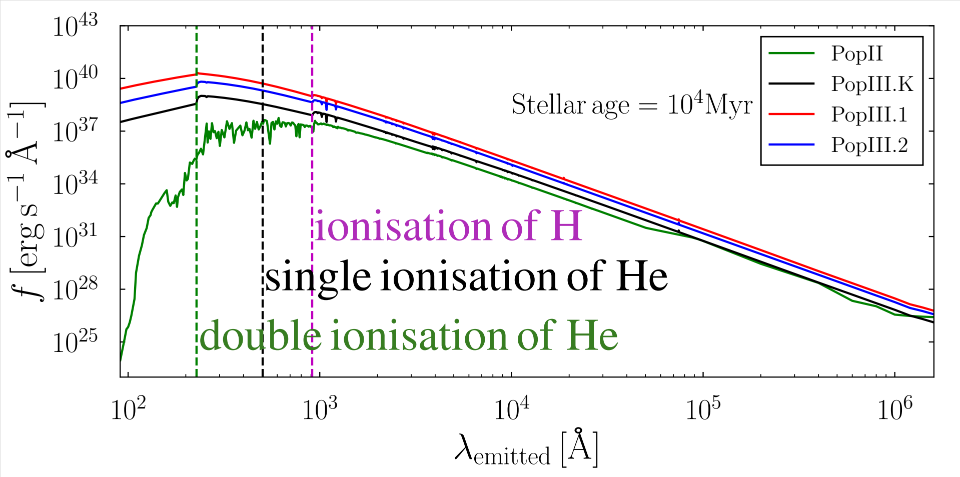

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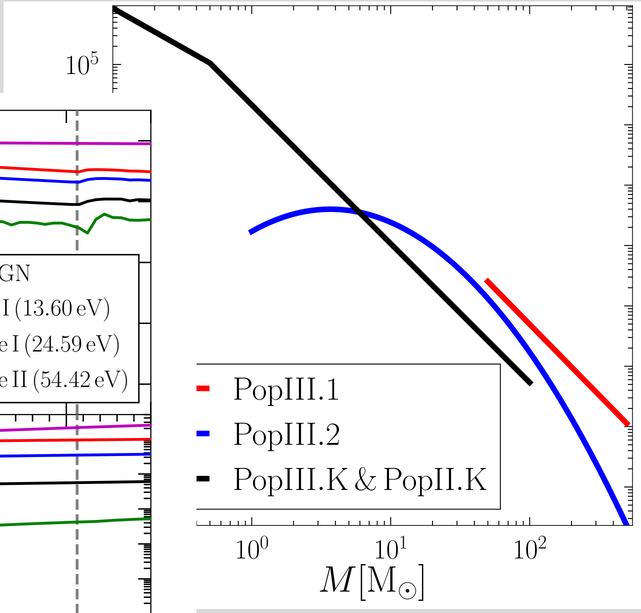

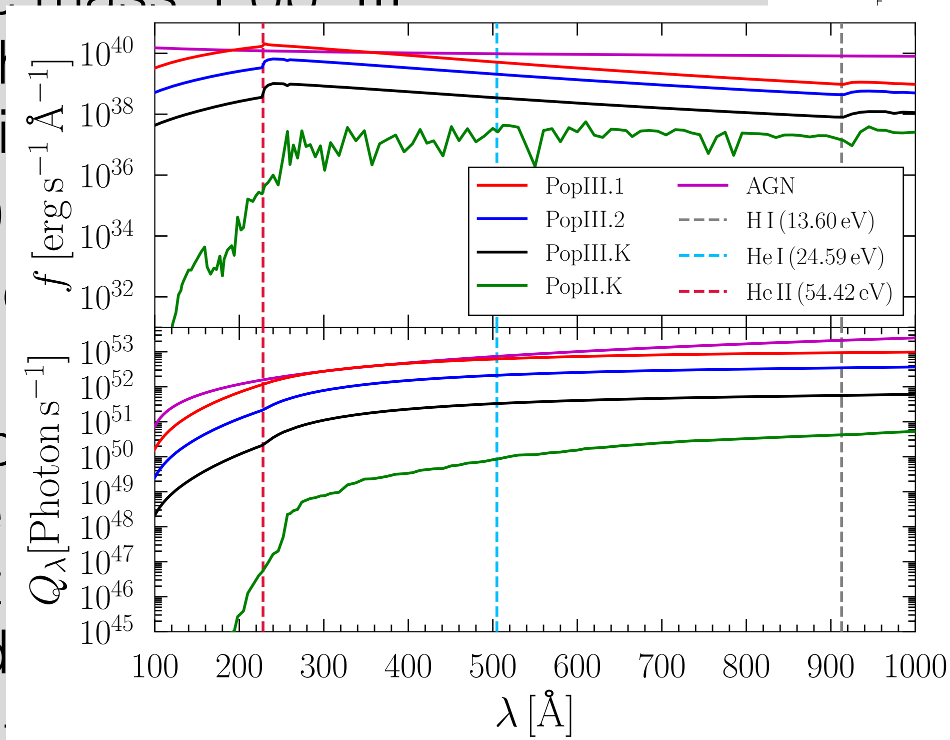

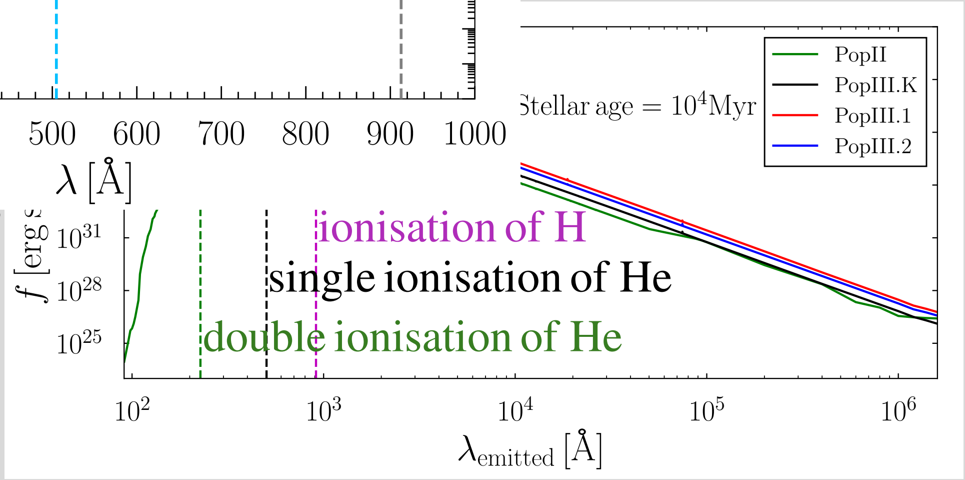

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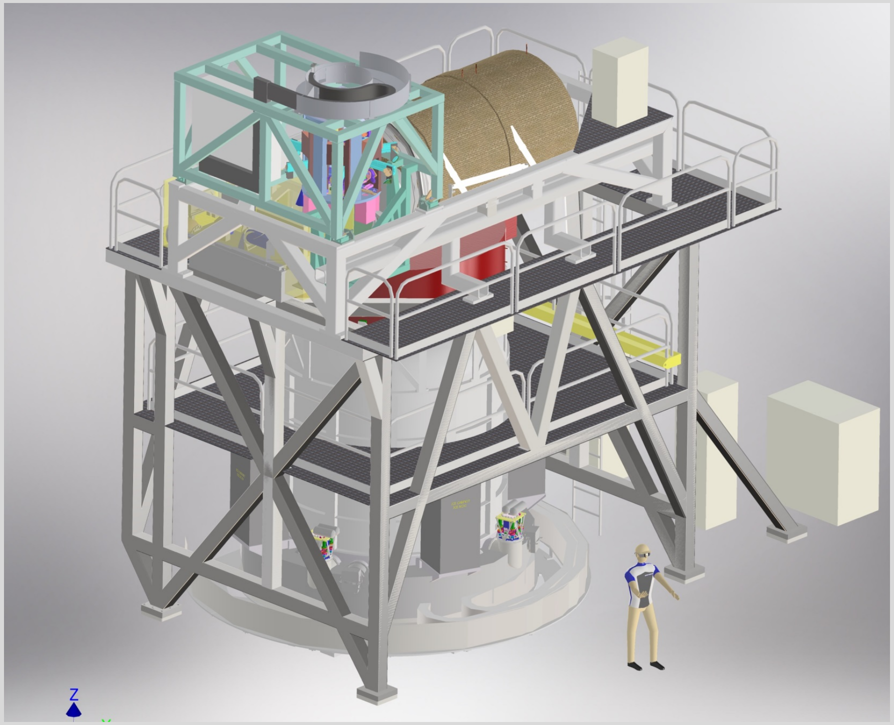
HARMONI

- ★First light general purpose Integral Field Spectrograph for ELT
- ★V-K ($0.45 - 2.45 \mu m$) spectral coverage
- ★R=3500,7000,17000 resolutions
- ★60,20,10 & 4mas pixel scales
- ★NoAO/LTAO/SCAO correction
- ★206x152 pixel field of view (image slicer with 32000 spaxels)



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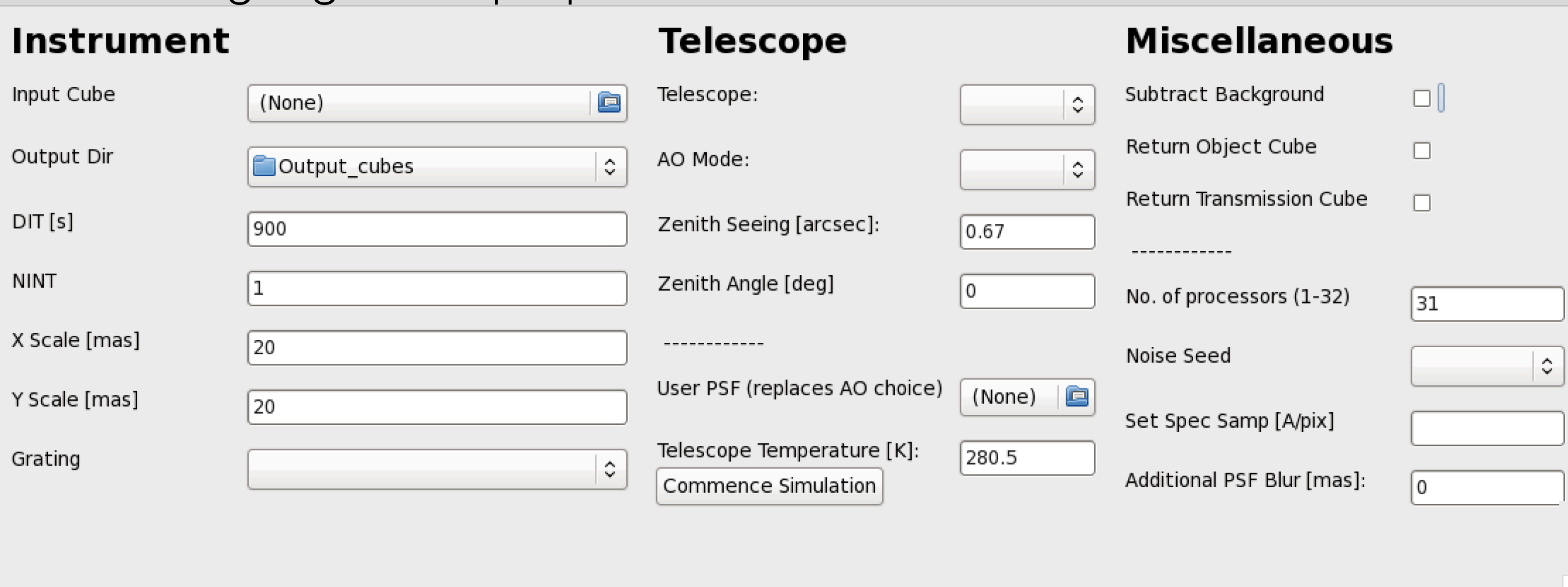
HARMONI

★First light general purpose



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All of which is simulated with HSIM (see Zieleniewski et al., 2015)

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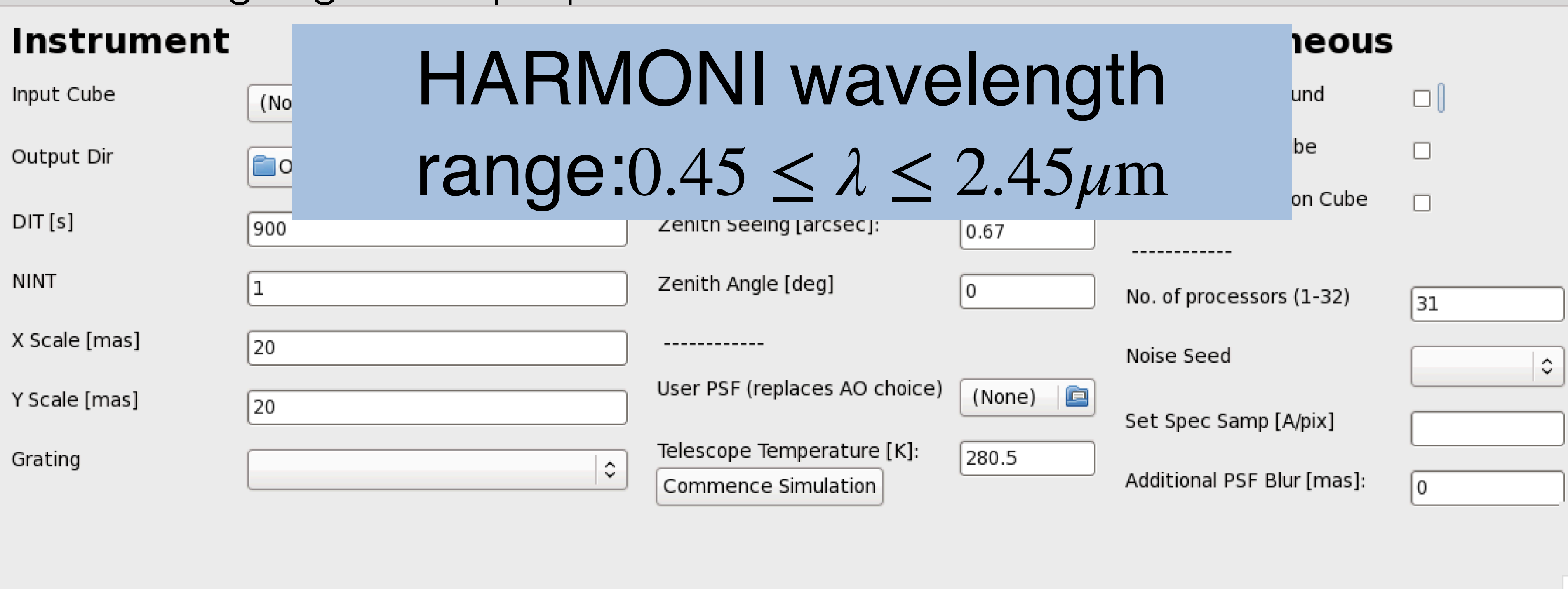

HARMONI wavelength range: $0.45 \leq \lambda \leq 2.45\mu m$

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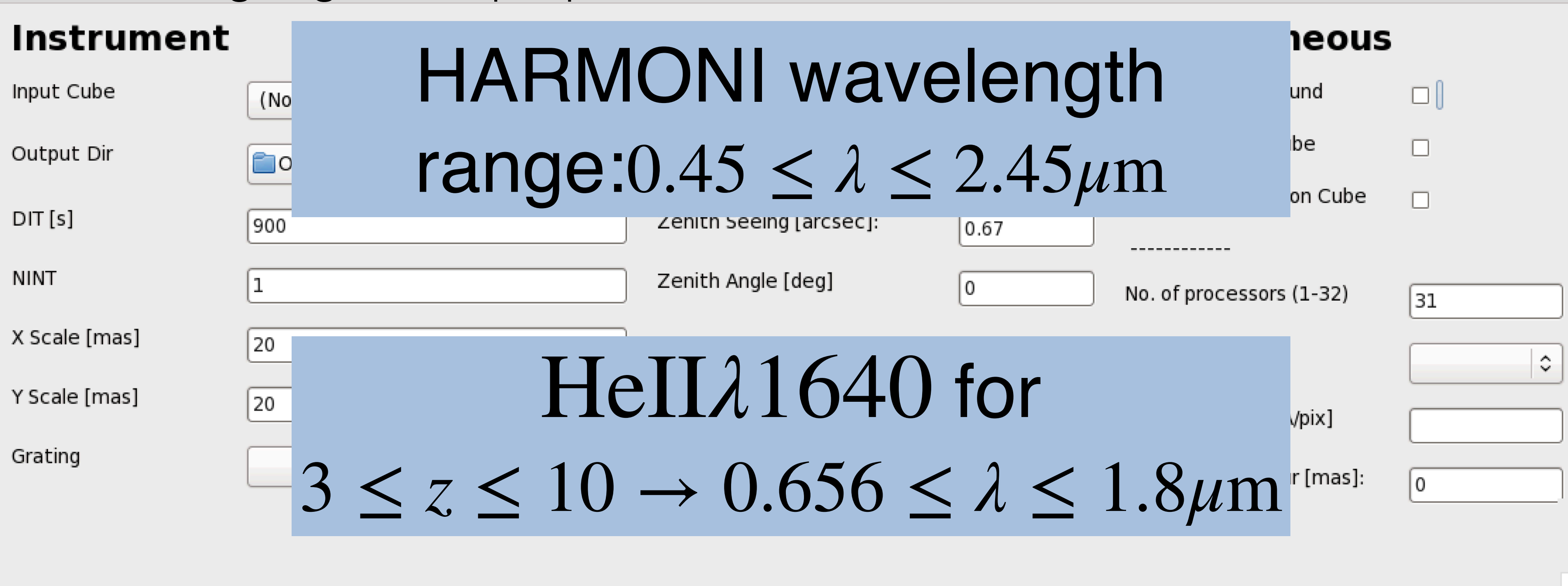

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$\mathrm{HeII}\lambda 1640$ for $3 \leq z \leq 10 \rightarrow 0.656 \leq \lambda \leq 1.8 \mu m$

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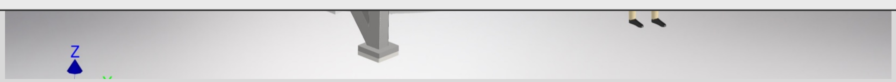

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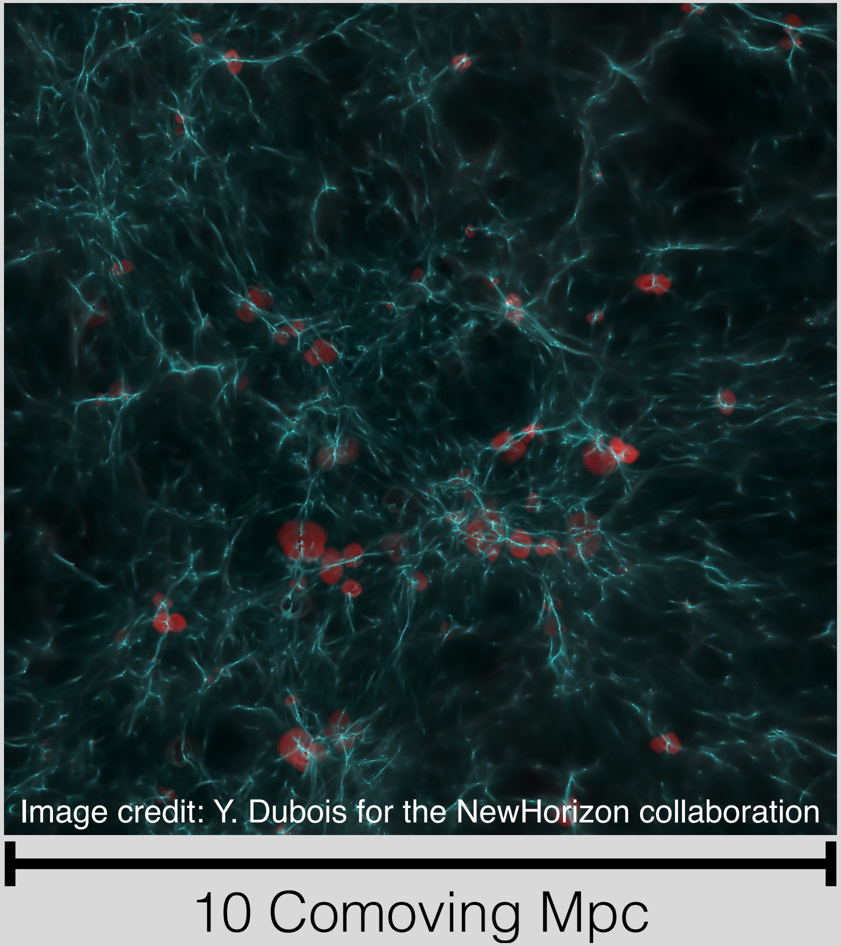
NewHorizon Simulation

- ⋆ New cosmological Hydrodynamical + N-Body simulation
- ⋆ Run from z~45 to z~0.7 with a volume of 20MPc
- ⋆ Use the Adaptive Mesh Refinement code RAMSES (Teyssier, 2002).
- ⋆ Includes: Gas, Dark Matter, Stars particles, Black Holes, star formation, stellar feedback and AGN feedback.
- ⋆ It has a maximum spatial resolution of $\Delta x \sim 35\,\mathrm{pc}$ and a mass resolution of $2 \times 10^5\,\mathrm{M}_\odot$
- ⋆ See Dubois et al., in prep and references within



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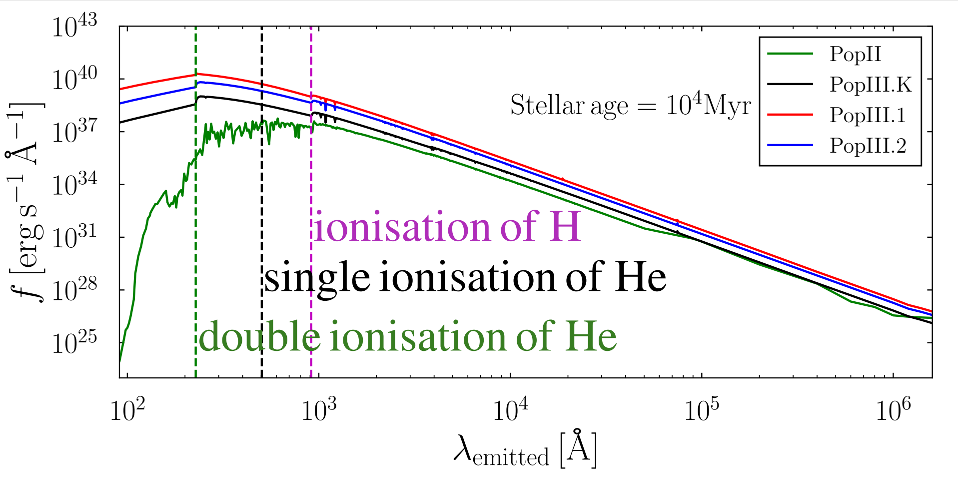

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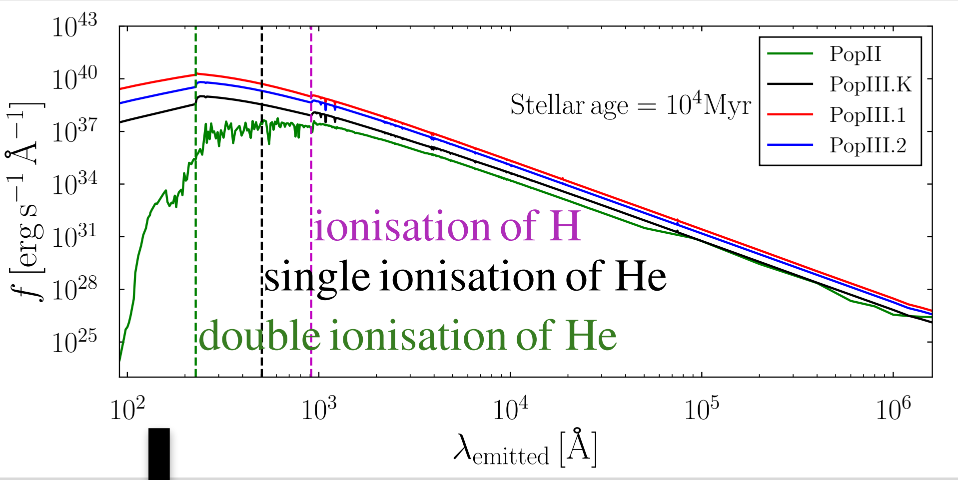

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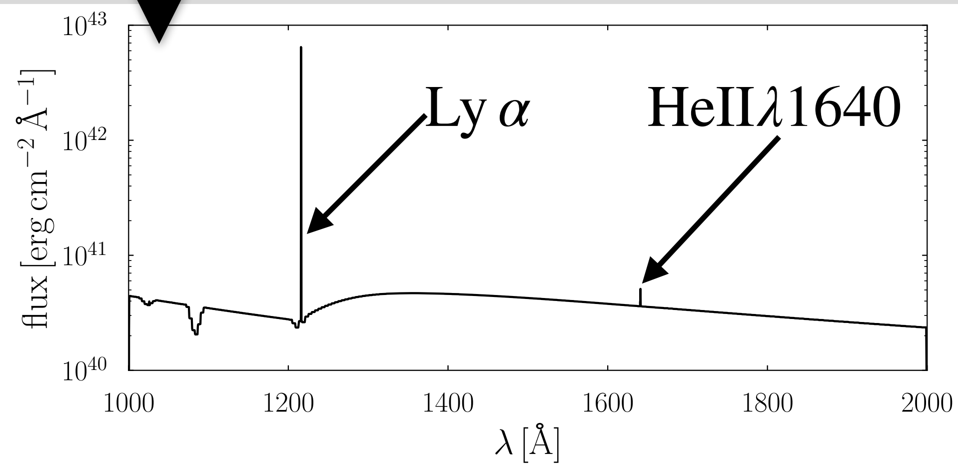

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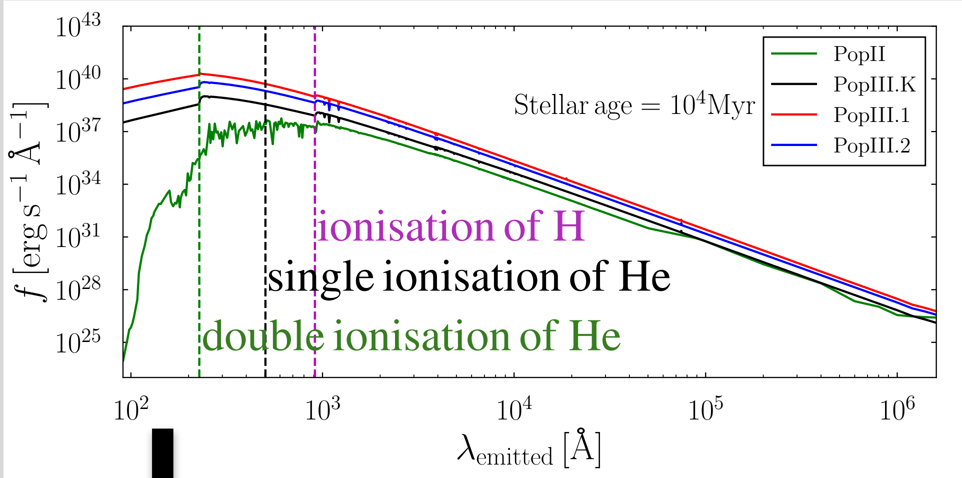
5) Observe the simulation using HSIM



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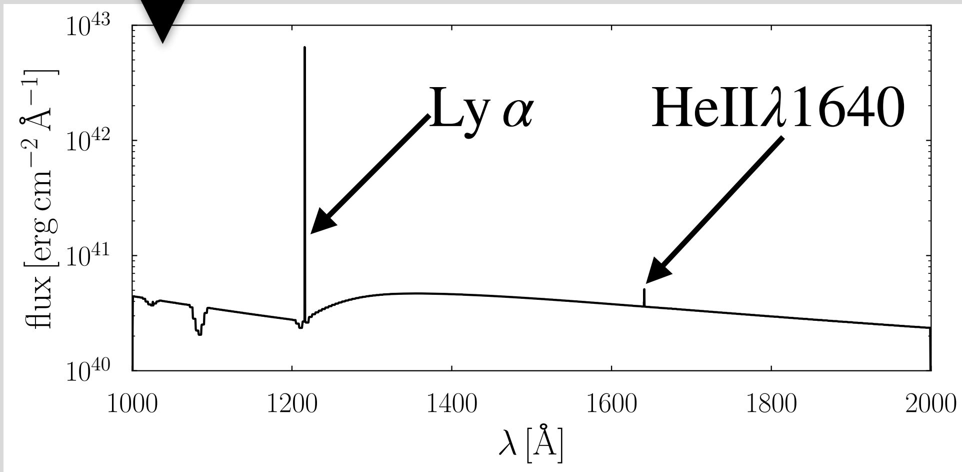

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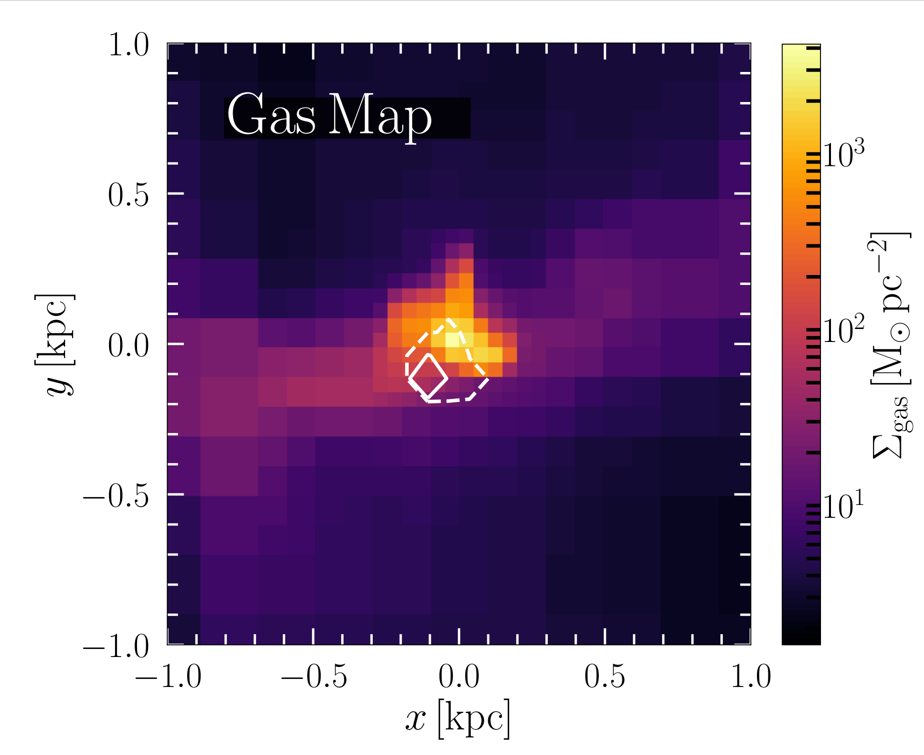
Observing Pop. III Stars

Recovered Galaxy Spectrum

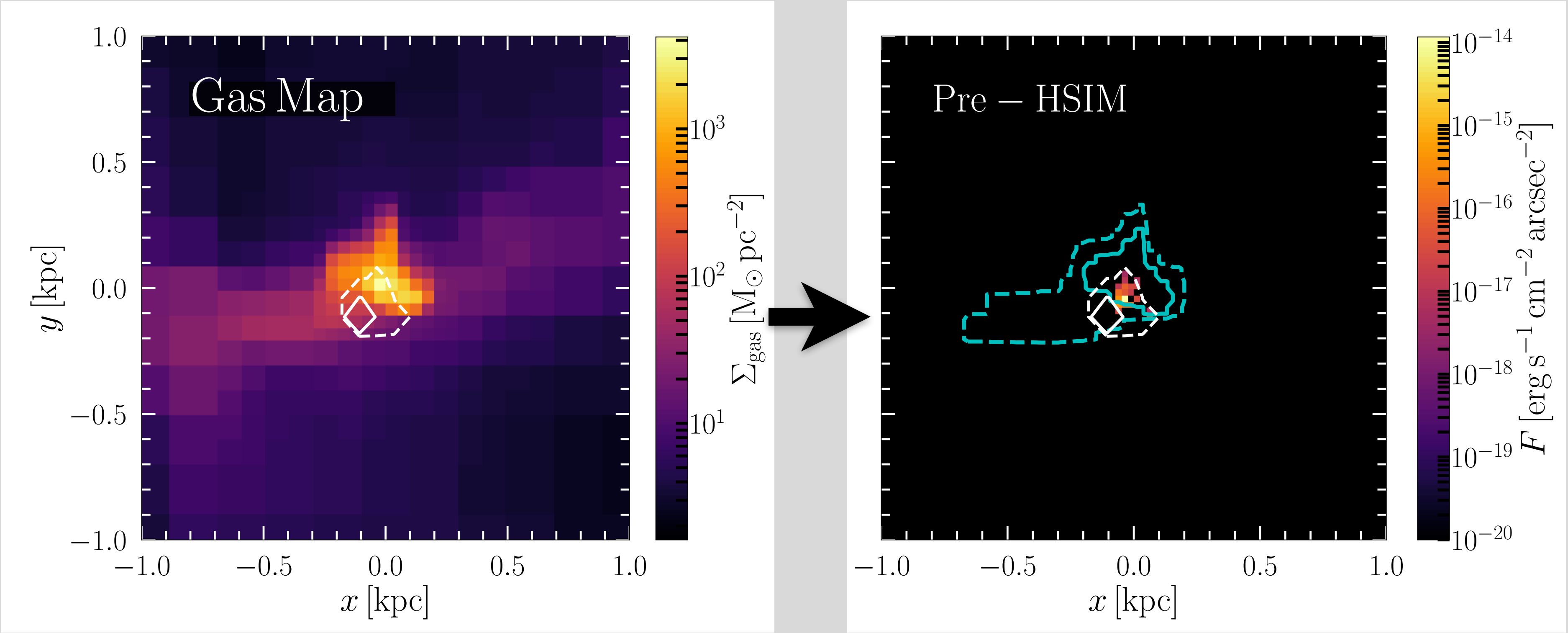


White Dashed Contour: $\Sigma_\star \geq 1\,\mathrm{M}_\odot$

White Solid Contour: $\Sigma_\star \geq 100\,\mathrm{M}_\odot$

Grisdale et al., in prep

Recovered Galaxy Spectrum



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Grisdale et al., in prep

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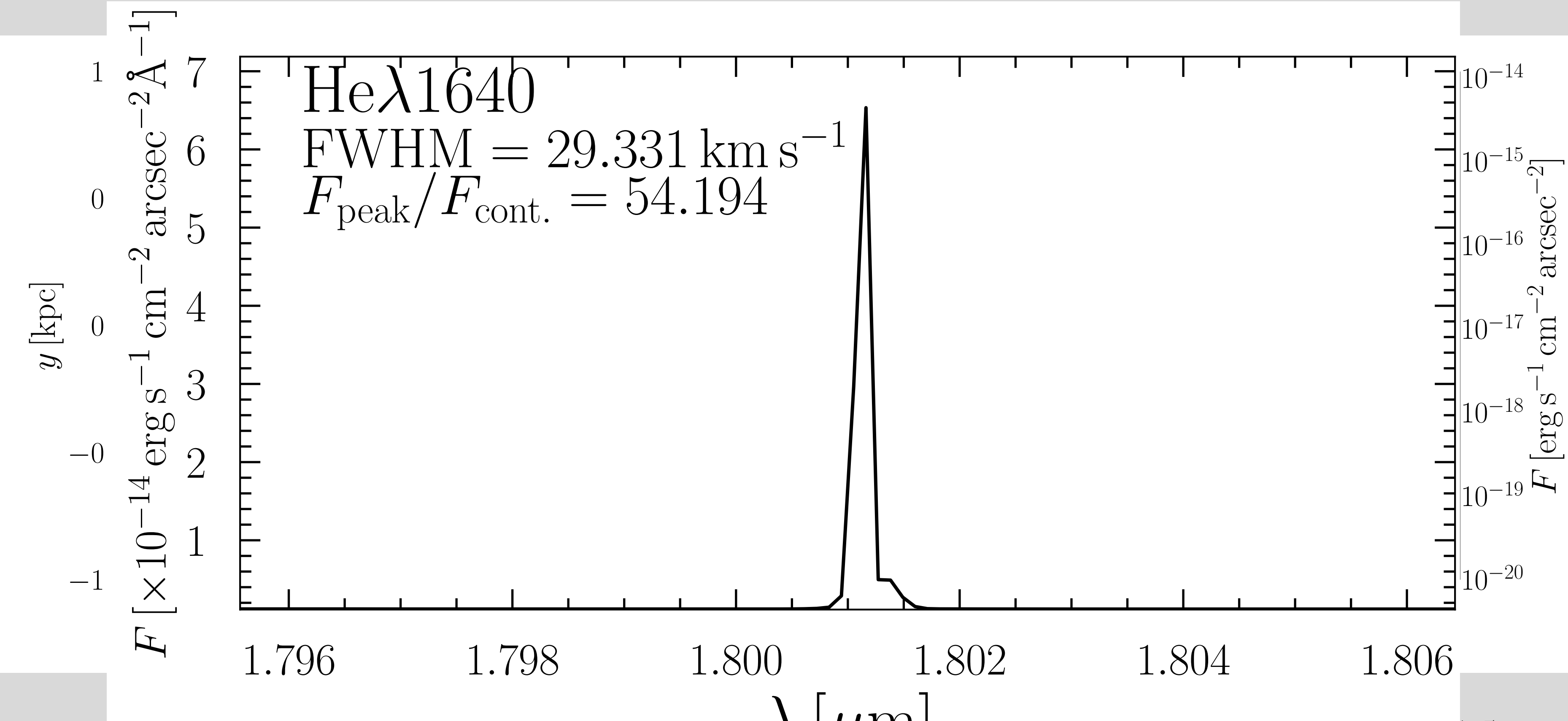

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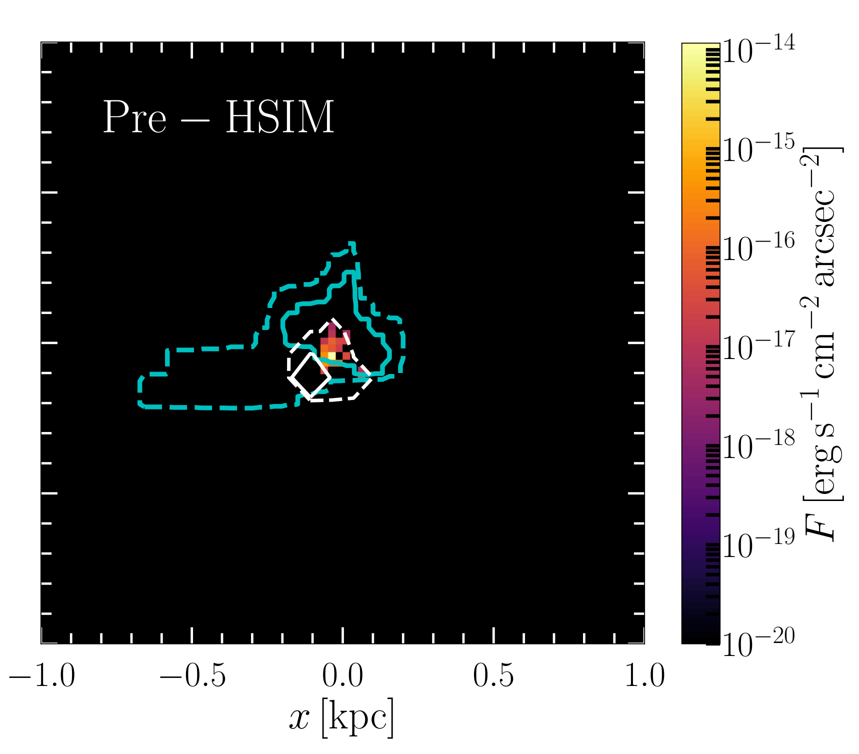
Can HeII1640 be observed?



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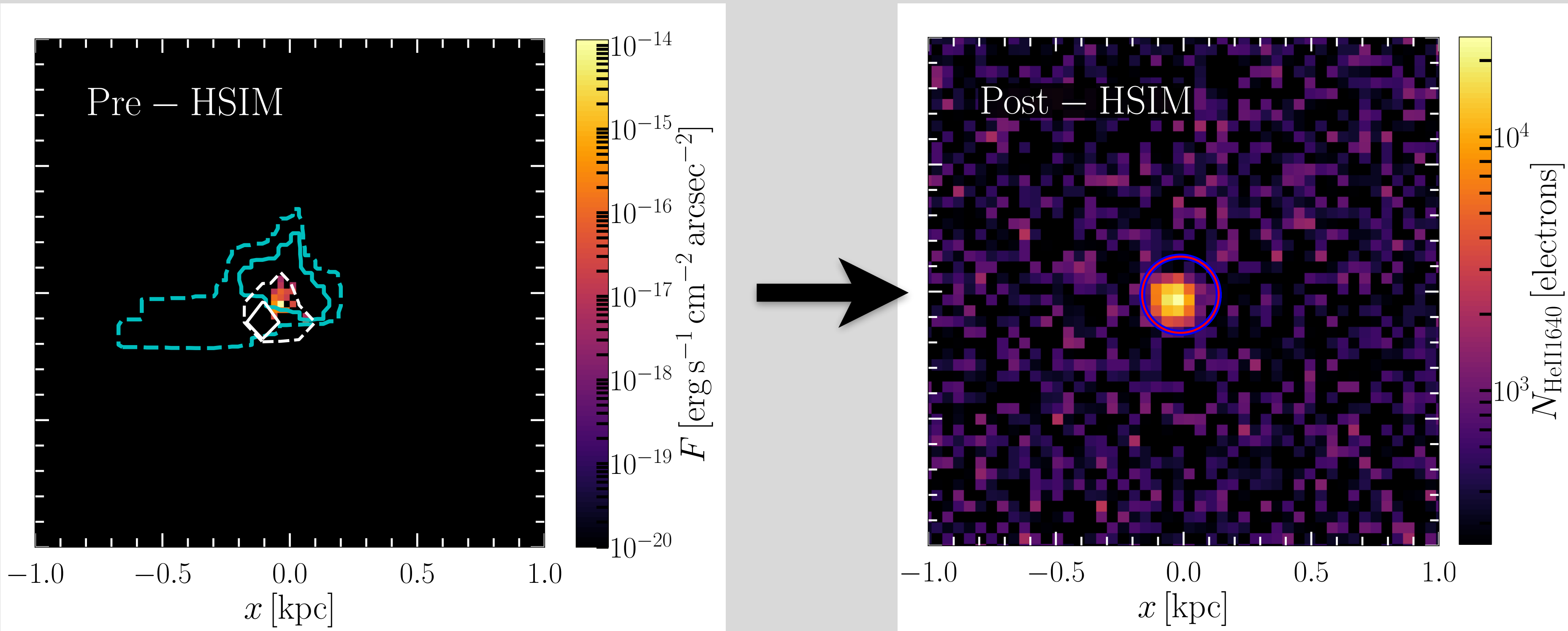
10 Hour observation with HSIM



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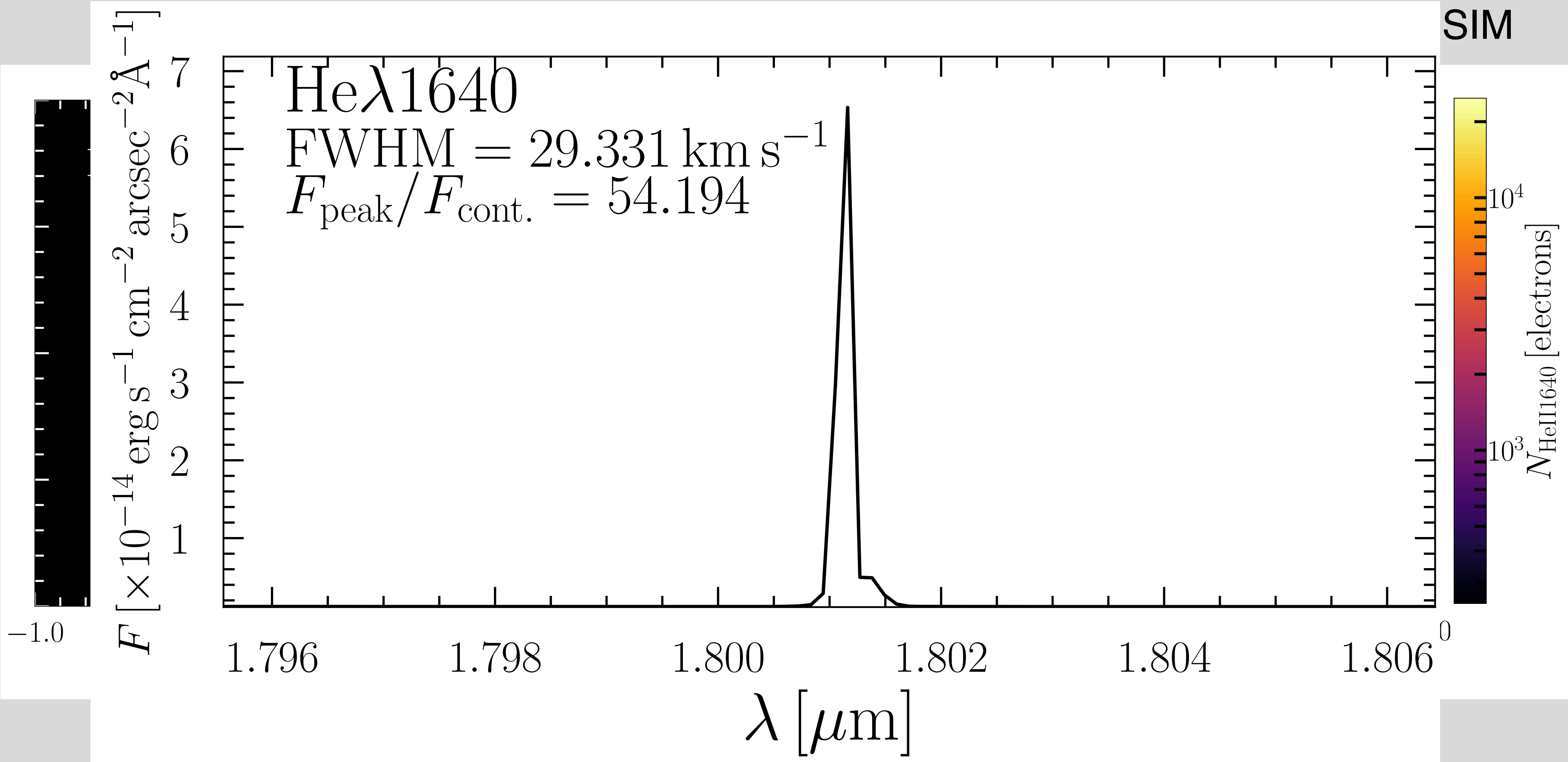

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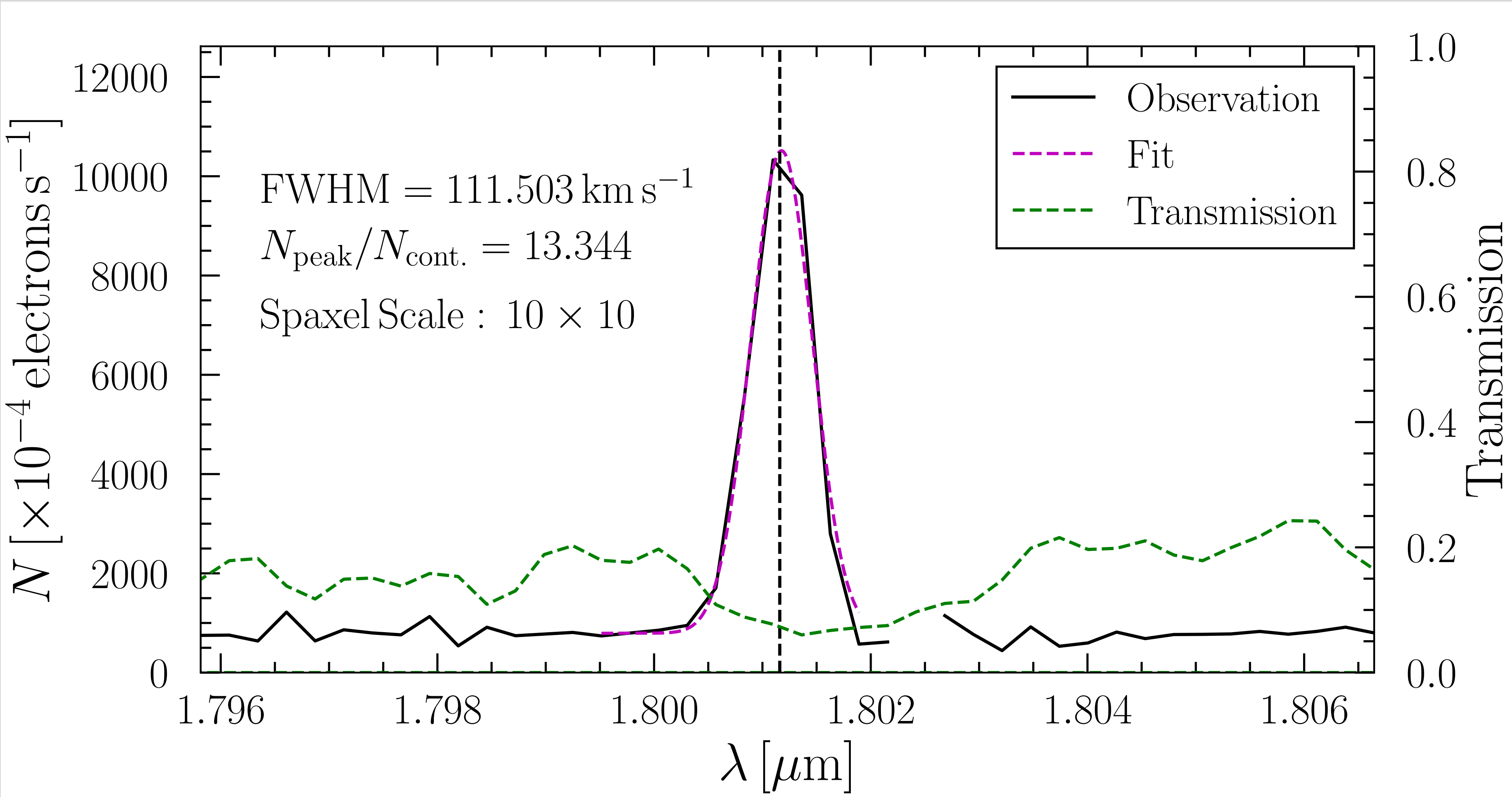
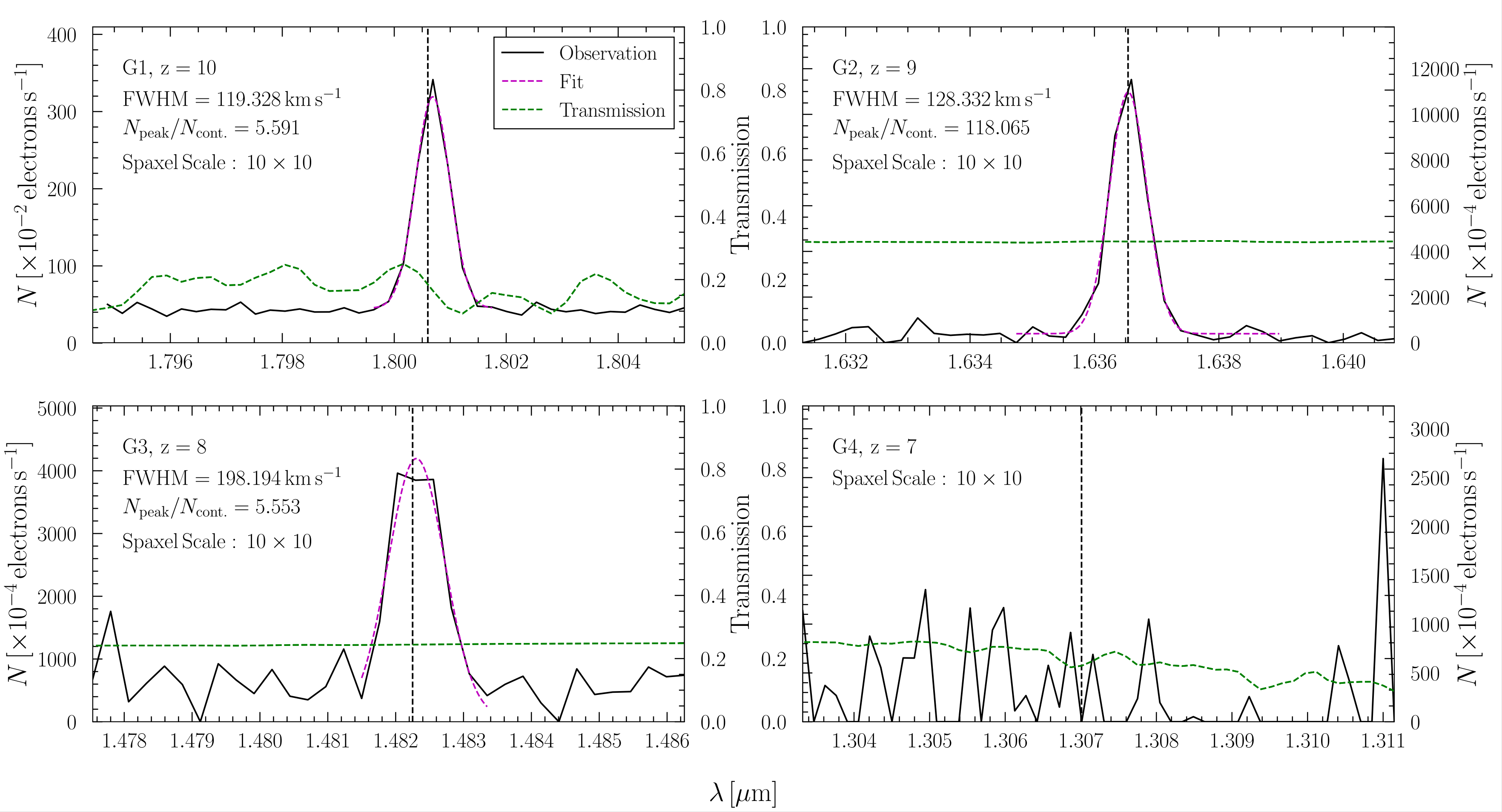


Grisdale et al., in prep

Observations at Multiple Redshifts



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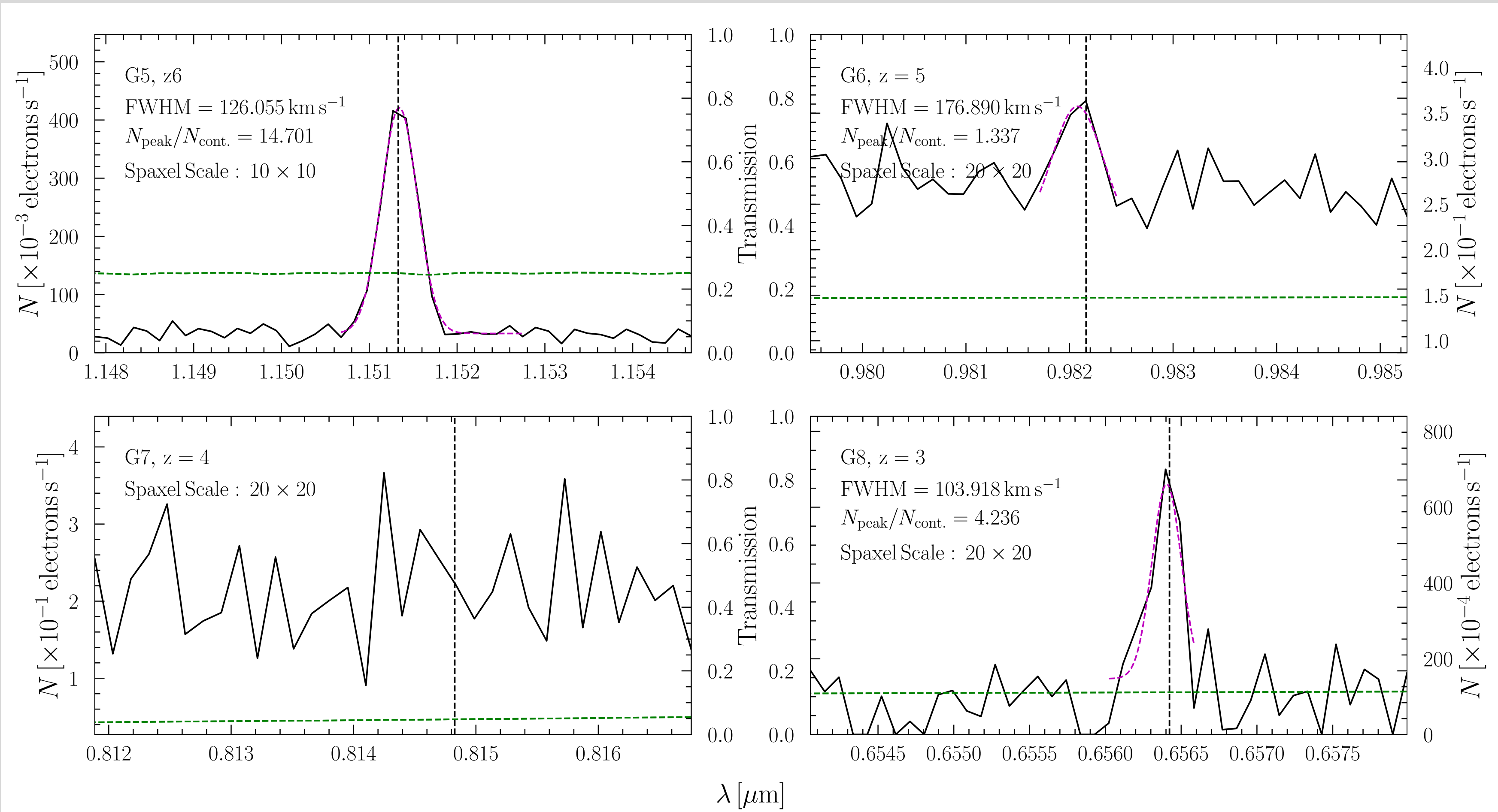
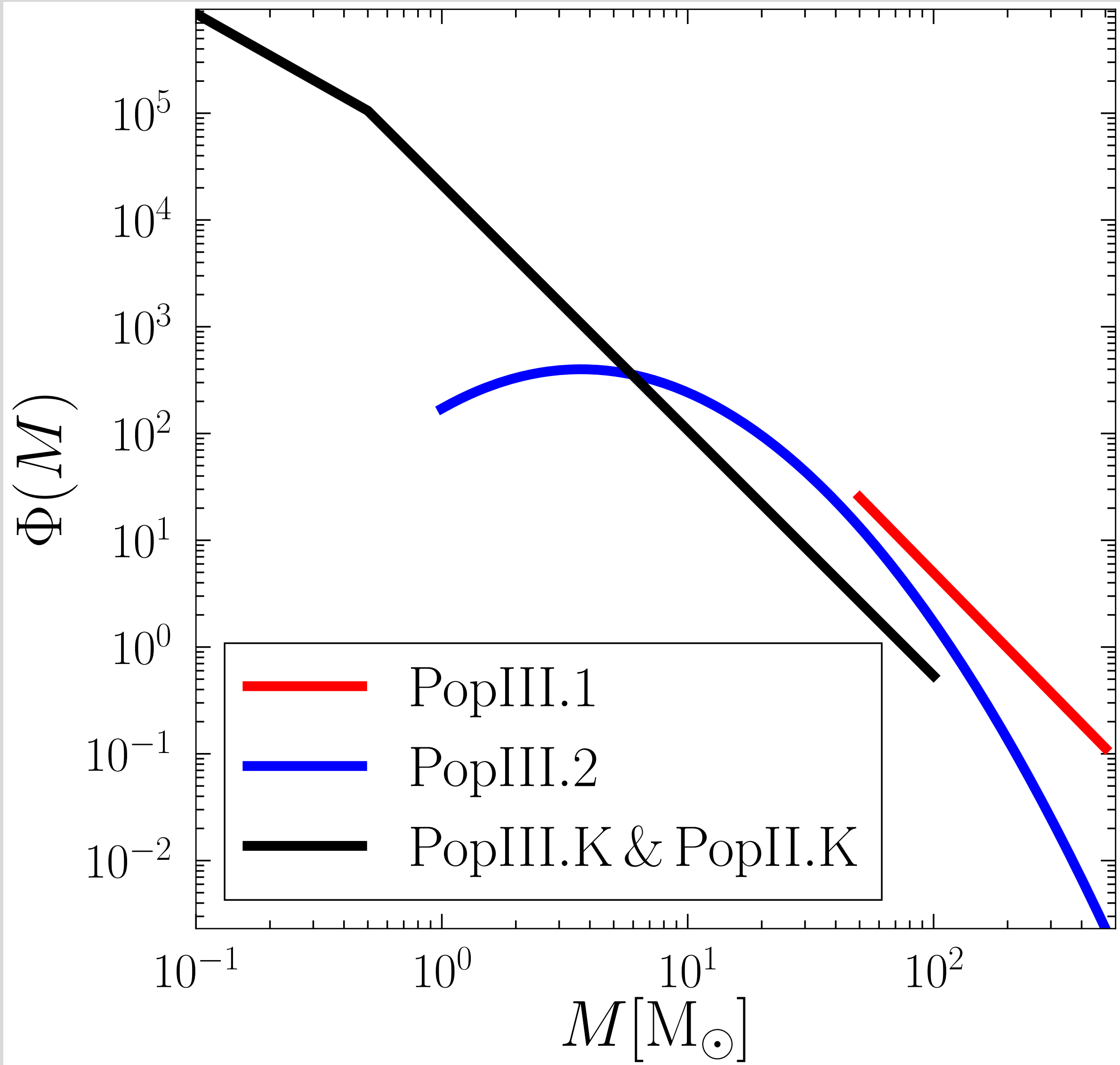


Impact of IMF



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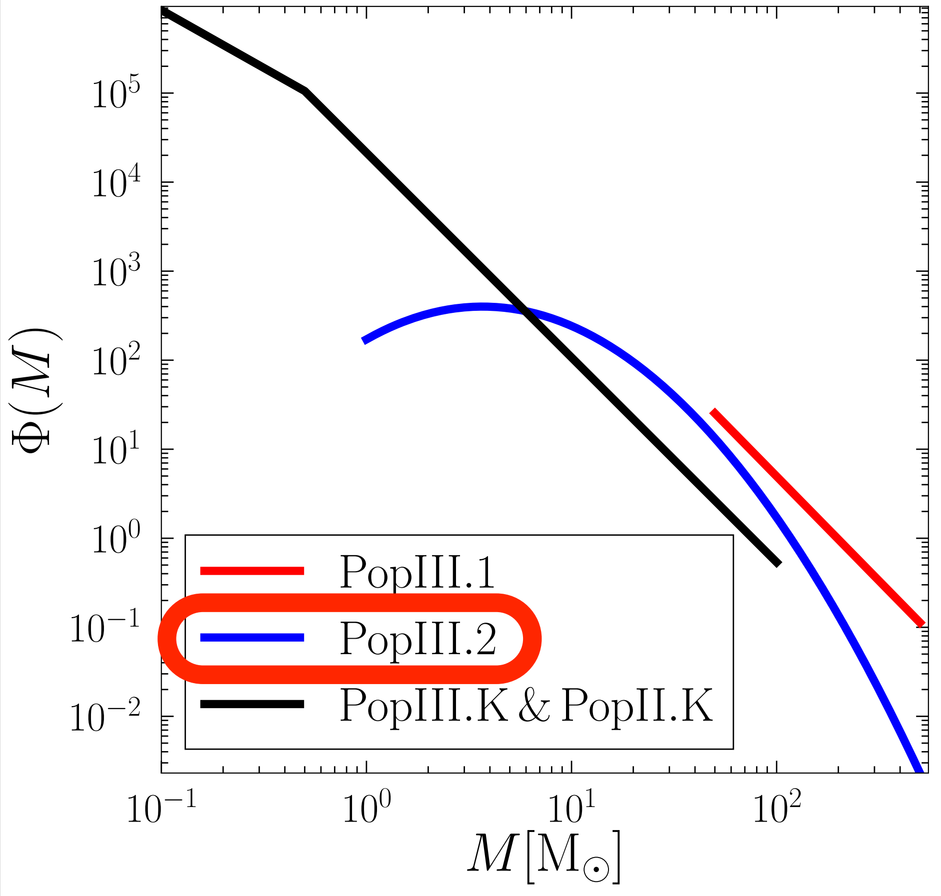
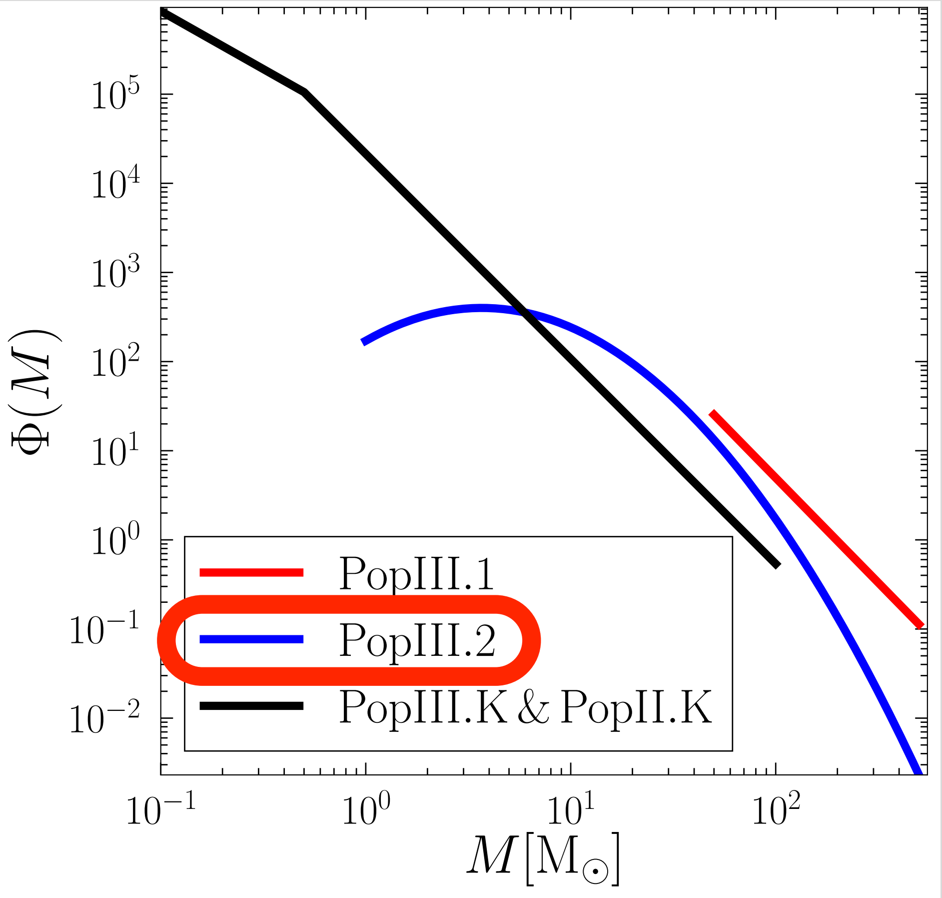
Impact of IMF: PopIII.2

★ 6 of 8 galaxies still produce $\mathrm{HeII}\lambda1640$ but in all cases the line strength is weaker.

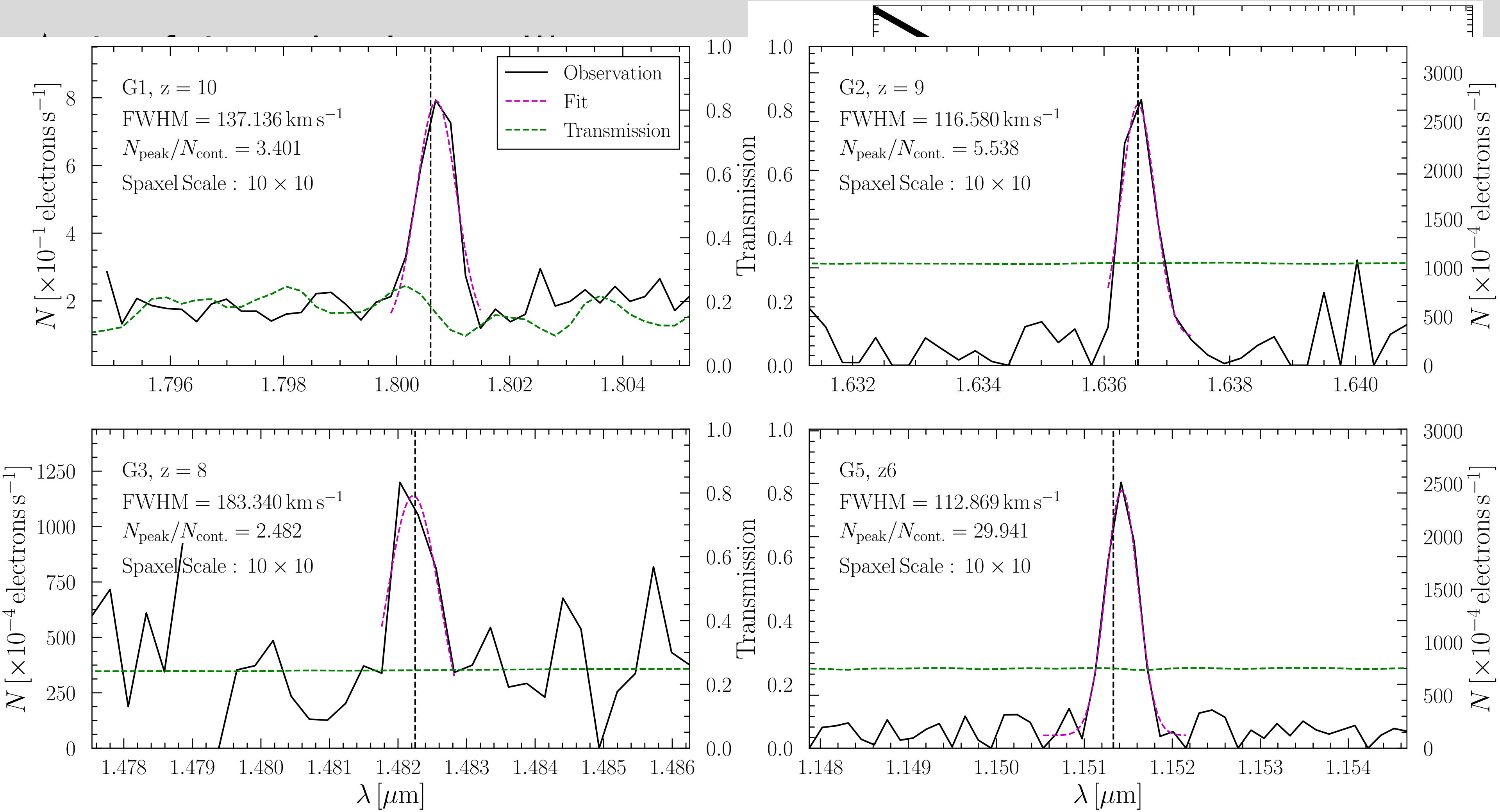


Impact of IMF: PopIII.2

- ★ 6 of 8 galaxies still produce **HeIIλ1640** but in all cases the line strength is weaker.
- ★ Only 4 of the 8 are now observable.

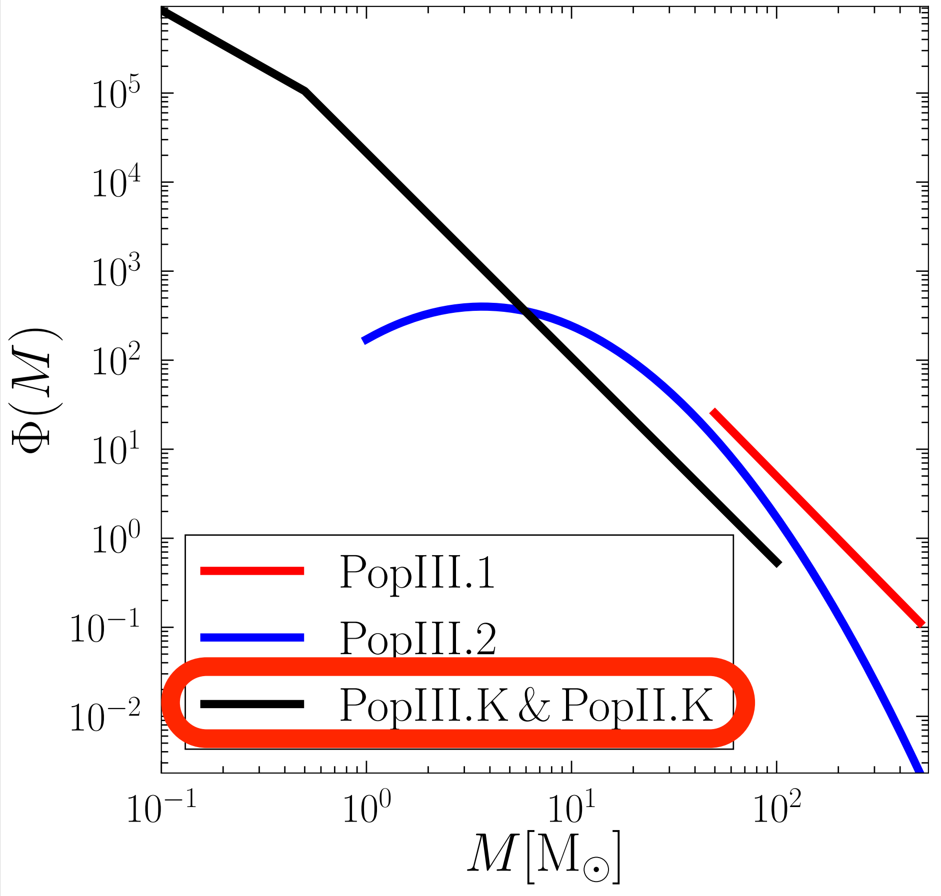


Impact of IMF: PopIII.2



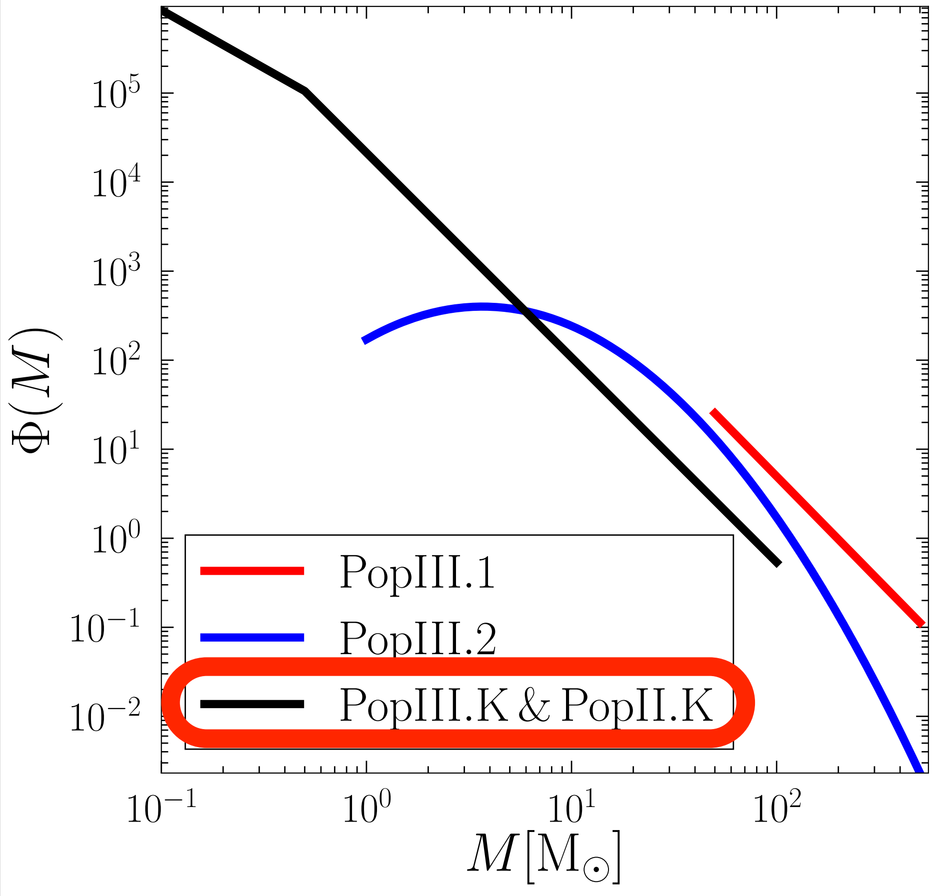
Impact of IMF: PopIII.K

★ Some galaxies produce extremely weak emission lines.



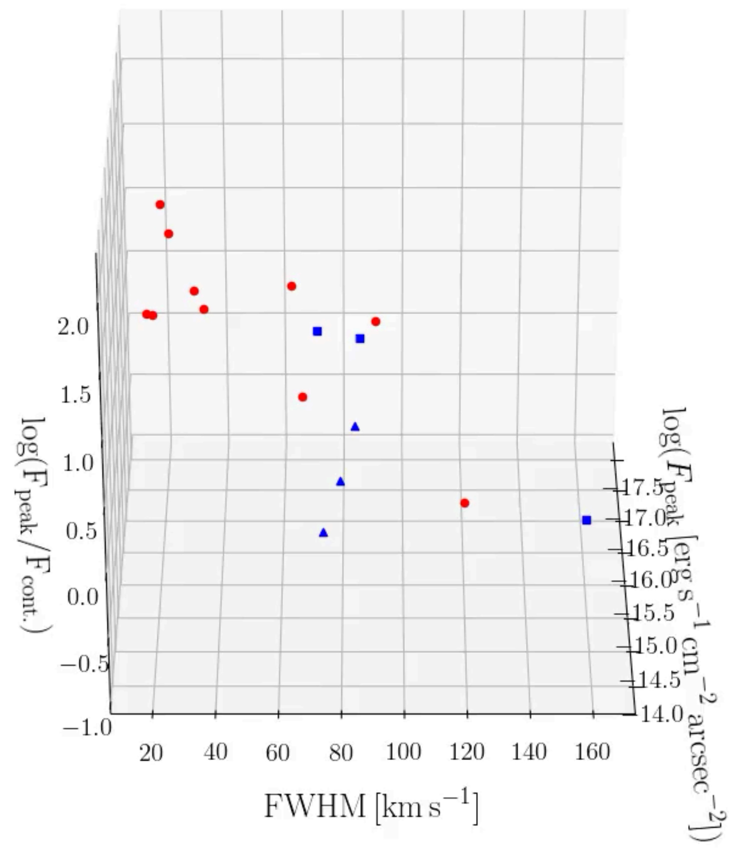
Impact of IMF: PopIII.K

- ★ Some galaxies produce extremely weak emission lines.
- ★ However ***none*** are observable.



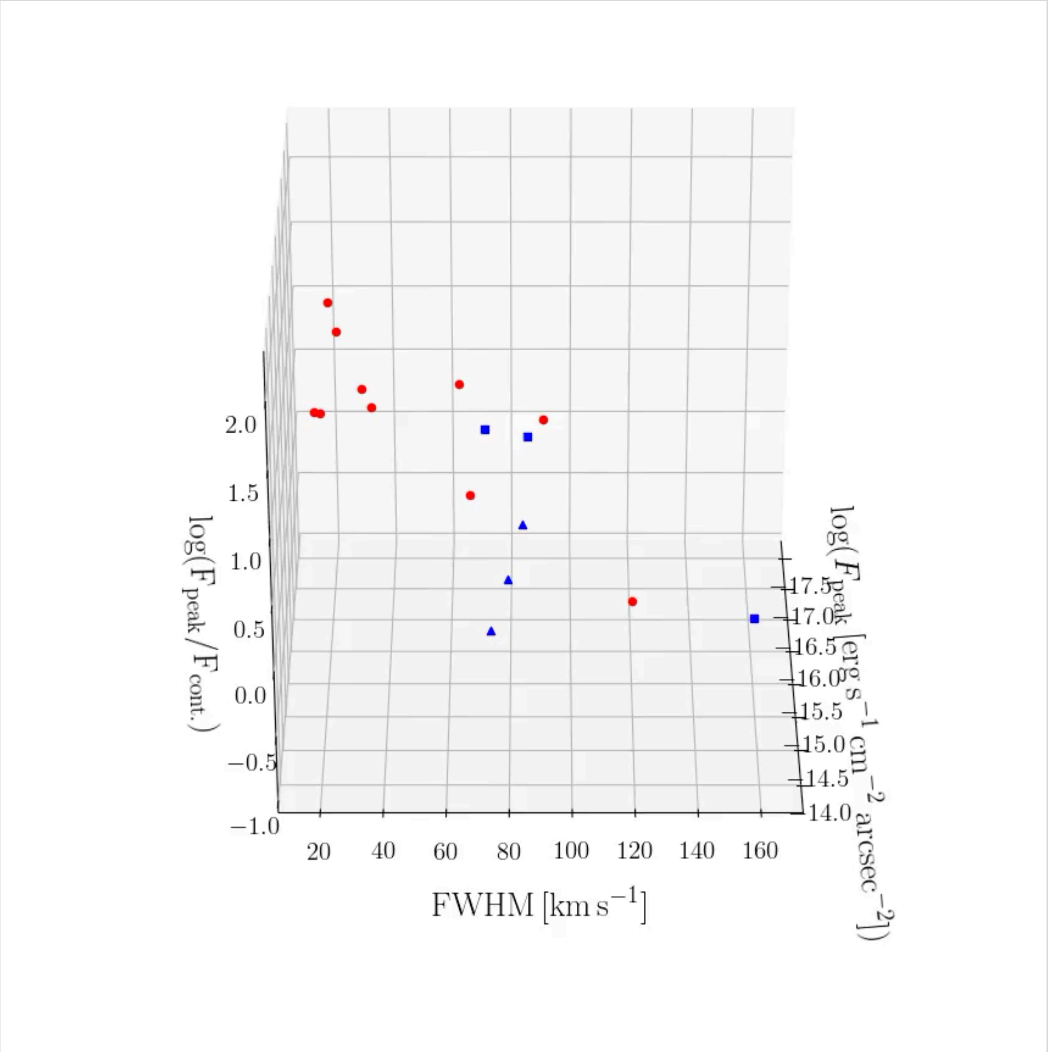
Detection Requirements

★ $F_{\mathrm{peak}} \geq 10^{-16}\,\mathrm{erg\,s^{-1}\,cm^{-2}\,arcsec^{-2}}$



Detection Requirements

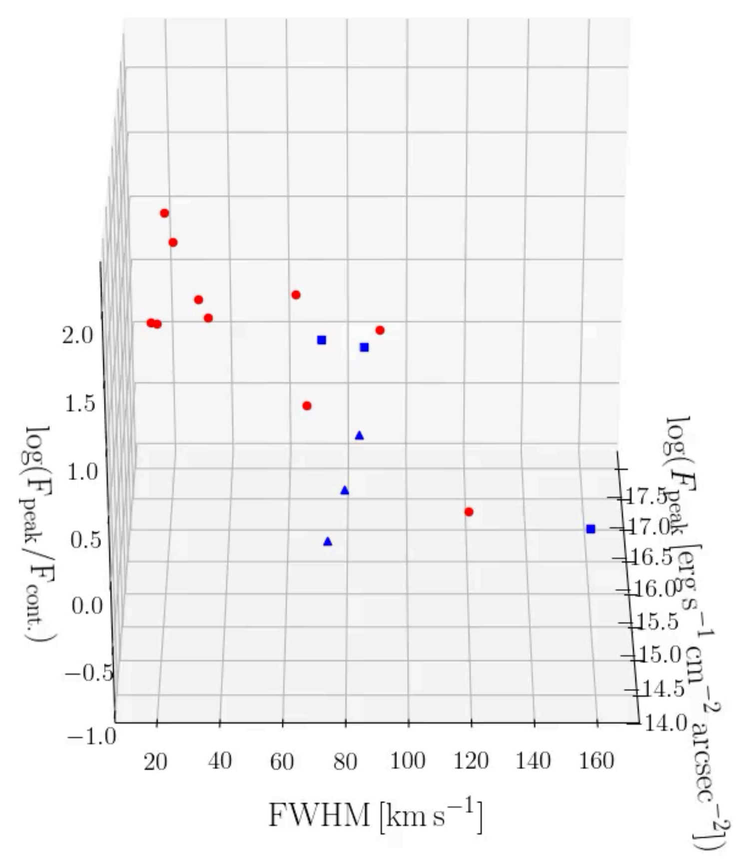
- ★ $F_{\mathrm{peak}} \geq 10^{-16}\,\mathrm{erg\,s^{-1}\,cm^{-2}\,arcsec^{-2}}$
- ★ $F_{\mathrm{peak}}/F_{\mathrm{cont.}} > 1.4$



CSIC Durham University UNIVERSITY OF OXFORD RAL Space Science & Technology Facilities Council UK Astronomy Technology Centre LAM ONERA CRAL irap IPAG ESO

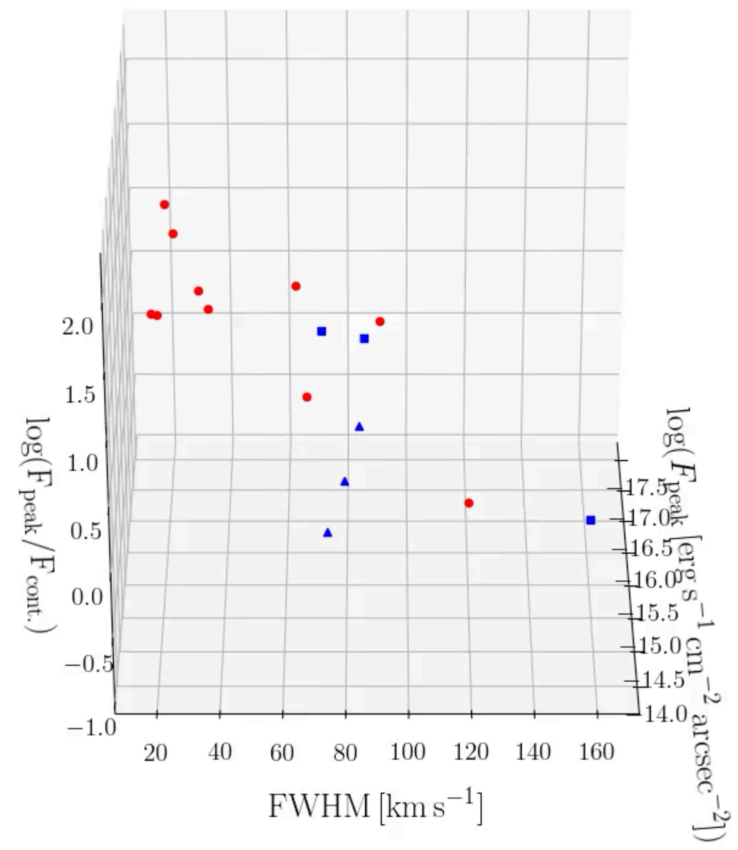
Detection Requirements

- ★ $F_{peak} \geq 10^{-16}\,\mathrm{erg\,s^{-1}\,cm^{-2}\,arcsec^{-2}}$
- ★ $F_{peak}/F_{cont.} > 1.4$
- ★ $20 \leq \mathrm{FWHM} \lesssim 100\mathrm{km\,s^{-1}}$



Detection Requirements

- ★ $F_{\mathrm{peak}} \geq 10^{-16}\,\mathrm{erg\,s^{-1}\,cm^{-2}\,arcsec^{-2}}$
- ★ $F_{\mathrm{peak}}/F_{\mathrm{cont.}} > 1.4$
- ★ $20 \leq \mathrm{FWHM} \lesssim 100\mathrm{km\,s^{-1}}$
- ★ In all cases, $\mathrm{HeII}\lambda1640$ detection will require target candidates from preceding observations.



Summary

Take aways:

- ★ Using High-res cosmological simulations, and HSIM it is possible to model observations of the PopIII for a given IMF and set of SEDs.
- ★ If the IMF of Pop. III stars is top heavy they will be detectable in observations via the $\mathrm{HeII}\lambda1640$ emission line for $3 \leq z \leq 10$.
- ★ If Pop. III stars follow a “traditional” IMF they are unlikely to be observed via the $\mathrm{HeII}\lambda1640$ emission line at any z.
- ★ Morphology of such galaxies is unlikely to be resolved.
- ★ Emissions form galaxies need to have a $F_{\mathrm{peak}} \geq 10^{-16}\,\mathrm{erg\,s^{-1}\,cm^{-2}\,arcsec^{-2}}$, $F_{\mathrm{peak}}/F_{\mathrm{cont.}} > 1.4$ and $20 \leq \mathrm{FWHM} \lesssim 100\mathrm{km\,s^{-1}}$ to be detectable.

Still to come:

- ★ “Observing” $\mathrm{HeII}\lambda1640$ in multiple galaxies at a given redshifts. Does Size/morphology etc. matter?
- ★ What impact does AGN have on the Pop. III signal.
- ★ Will observations provide constraints on PopIII IMFs?

Near-IR Spectroscopy with the ELTs

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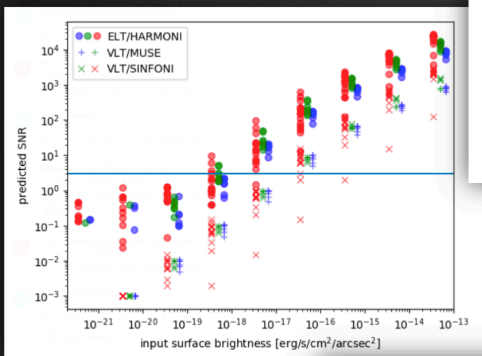
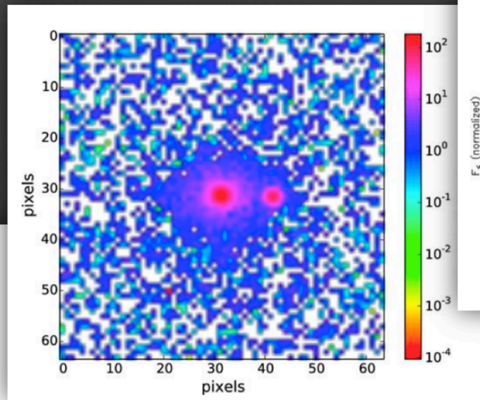
Dept of Physics Oxford

Save the date!

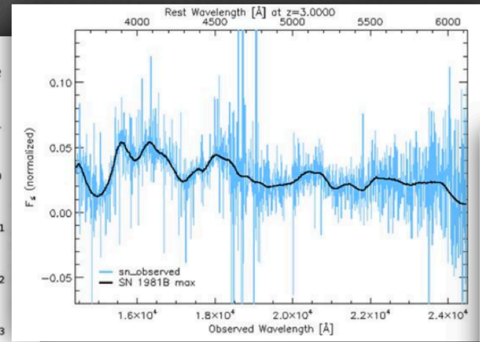
Science cases & simulations



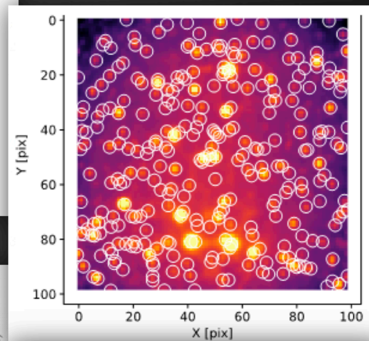
CGM: *Augustin et al, MNRAS acc*

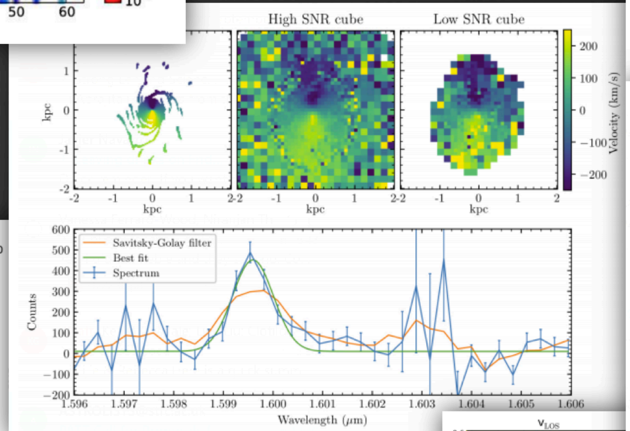


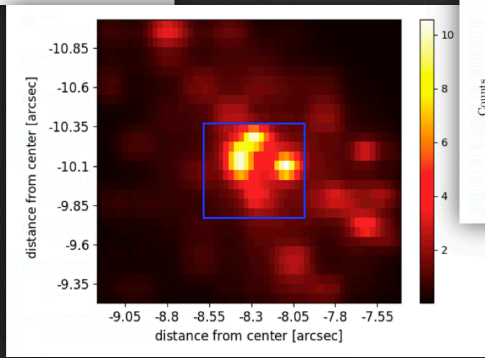
High-z SNe: *Boussinou et al 2018*



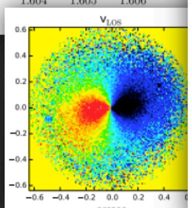
Resolved Stellar pops: *Gonzalez*

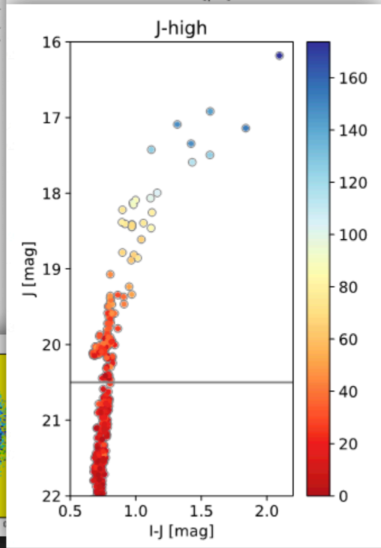






High-z Kinematics: Kendrew et al. 2016 *Richardson et al. subm*





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